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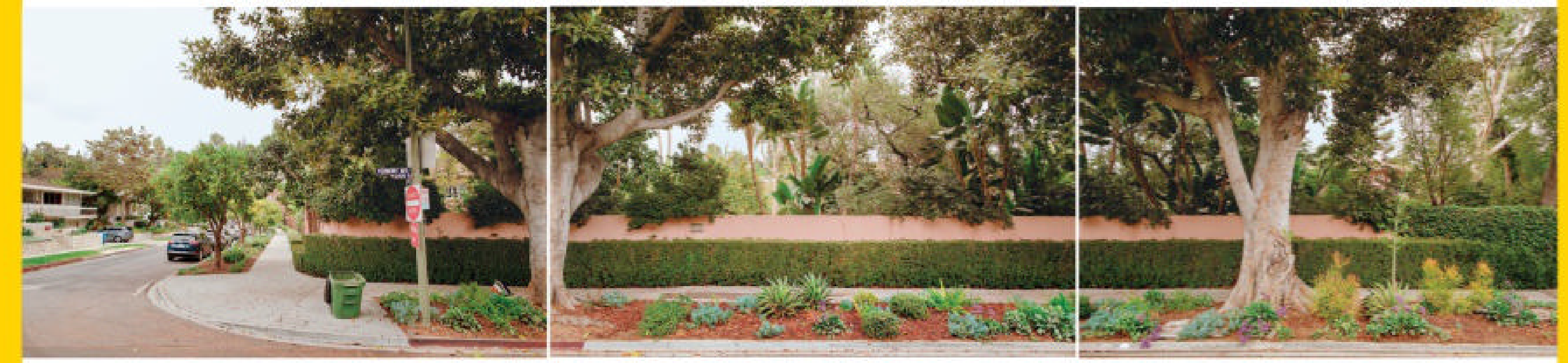


Along one Los Angeles street, wealthy areas are shady and cool.

The tree canopy decreases and temperatures rise as you drive south.

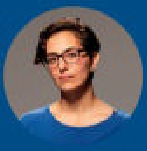
On a warming planet, this divide between rich and poor leaves many at risk.

BEATING THE HEAT

A **Better Path** for Plastic

Plastic plays an essential role in modern life, serving as a building block for everything from packaging to medical equipment. This versatile material has undeniable upsides—but far too much of it ends up in landfills or in our environment. What can each of us do to be part of the solution? Here's some inspiration for how you can make a positive impact in your community and the world.

> **"We believe that people have the capacity to influence leaders, big brands, policymakers—not just with their purchasing power, but as a force for change in the entire plastics ecosystem."**



Lilly Sedaghat
National Geographic Explorer

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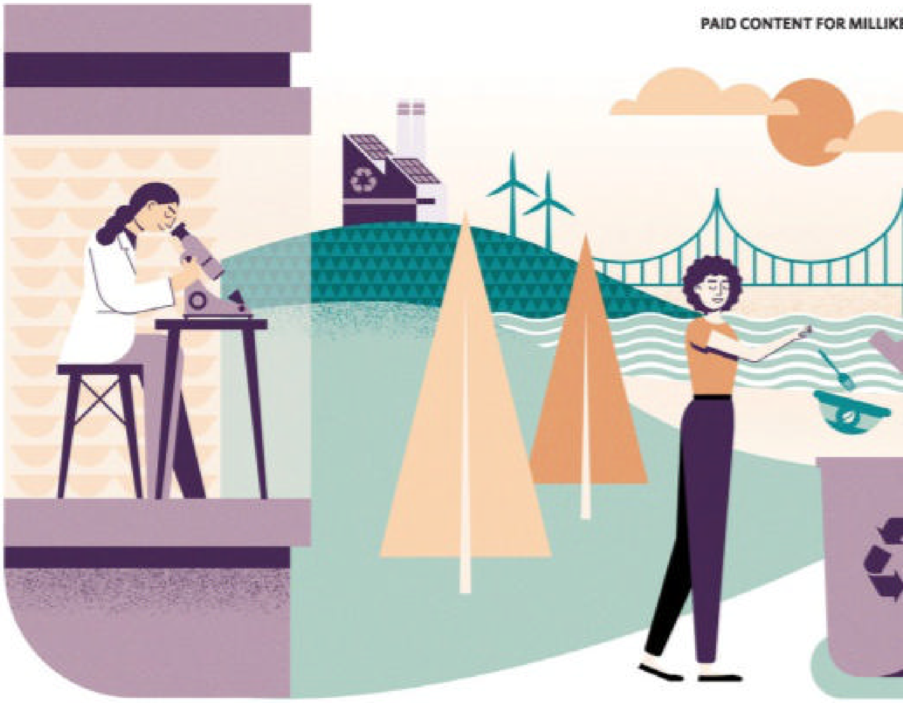

Solutions in Action

Initiatives that encourage repair, reuse, and recycling to reduce plastic waste come from every part of society and from every corner of the world. In India, some shops have begun treating recyclables as a form of currency redeemable for groceries. In the U.S., Phoenix—once branded the world's least sustainable city—now has set an ambitious goal to be zero waste by 2050, and other cities are setting their own zero-waste targets. Plastic waste is a complex problem that will require markets, infrastructure, and leadership to solve. "We shouldn't be afraid of complicated problems," said Keefe Harrison, founder and CEO of The Recycling Partnership. "We just need systems solutions that address the complexity."

QUESTION

Compared with new PET* plastic, how much energy does recycled PET save?

A) 33%
B) 50%
C) 79%
D) 91%

*polyethylene terephthalate

ANSWER: C Recycled polyethylene terephthalate (PET) plastic uses 79 percent less energy than new, or virgin, plastic. Recycled high-density polyethylene (HDPE) and polypropylene (PP) each use 88 percent less energy.

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Virtual Ideas Exchange

rteen experts from around the world hered virtually in March 2021 to discuss the l-of-life challenges for plastics and some cessful examples of positive change. The ticipants came from local governments, environmental groups, businesses, and universities. Across three dynamic breakout sessions, they outlined what must happen now to stop plastic waste—and described heartening examples of change already under way.

Milliken.

For Milliken, a global manufacturer that convened the event in March, finding solutions for end-of-life plastics is a sustainability goal for the company. "We are a technology player in the ecosystem of plastics," said CEO Halsey Cook. "We have a responsibility to think intentionally about where our products go and how they are managed in the future."

What **You** Can Do

Be a Community Leader

Solving big challenges requires leadership from our elected officials, from businesses, and from each one of us. As parents or mentors, we can teach and encourage positive behaviors in others. In our work lives, we can drive change within our own companies. As voters, we can challenge our legislators to adopt policies that require more sustainable systems. And as everyday citizens, we can share what matters to us in conversations and on social media.

Stay Curious

Waste is a problem that is growing right before our eyes. Making decisions about what types of products to buy—or whether to purchase them at all—can feel overwhelming. Start by asking questions about the products that you're using. What is it made of? How long will it last? Is it recyclable or compostable in your area? Is there an alternative? Then look for products that contain recycled materials and are designed from the start with circularity in mind.

Change Your Perspective

Placing recyclable and compostable items in their appropriate bins whenever you can is very important—but that's not all you can do. Consider ways to buy less and reuse more, such as choosing refillable packaging. See if your community offers repair workshops as a way to keep items working longer. Neighborhood groups and thrift stores are a great way to pass on what you no longer need and pick up necessities without buying new things.

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Tree canopy—which helps to lower temperatures—differs markedly along Los Angeles's Vermont Avenue, as seen in this series of photos.
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PHOTOGRAPHS BY MEDINA SAGE DUGGER

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A think tank's mocking awards call out waste, greed, and dysfunction in health-care systems.

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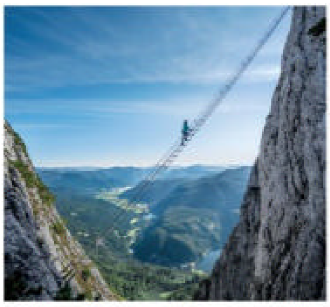

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Founded 170 years ago in America, they're still reinventing themselves.

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ABOVE: Conservator Xènia Aymerich looks at the partial skull of an extinct false saber-toothed cat, one of a trove of important fossils uncovered during expansion of a Barcelona landfill.

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CURBING CLIMATE CHANGE

One Nation, Under Heat and Shade

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **ELLIOT ROSS**

SCIENCE TELLS US unequivocally that the world is getting hotter: The past six years have been the warmest on record.

Each of us may note this differently. For me, it's the birds that no longer migrate south in the winter; I see them all year long now. And why in the world is the forsythia blooming in January?

Ultimately, to solve global warming, we must drastically reduce greenhouse gas emissions. Part one of this month's cover story package addresses that challenge. It looks at heat and how humans—who evolved during the past 10,000 years in an average air temperature of 55 degrees Fahrenheit—must adapt to a steamy new reality but also work to mitigate it.

Part two of the package explores a low-tech, immediate solution to heat: shade. We're well aware of its public health benefit, as being in the shade can make us feel up to 20 degrees cooler than if we were in the sun. That principle applies to where we live as well. A recent study found that neighborhoods with dense tree canopy and parks and other open spaces averaged about five degrees cooler than neighborhoods without those attributes—in the very same cities. We tell our shade story from Los Angeles.

You likely won't be surprised to learn that the hotter neighborhoods tend to be lower-income areas where people of color form a larger share of the population. Redlining and discrimination have long denied people home loans and stifled community investment. The legacy of those inequalities makes shade itself a fraught commodity. It's not just a way to keep cool; it's a lasting measure of privilege on one hand and environmental racism on the other.

"You just don't see green in the areas that were redlined," urban ecologist Vivek Shandas told our writer Alejandra Borunda. Today in some of L.A.'s poorest neighborhoods, the percentage of land shaded by the tree canopy is in the single digits (compared with nearly 40 percent coverage in better-off neighborhoods). Shandas, who studies urban forest equity, is working with the city of Los Angeles to develop tree-planting programs.

And here's the good news: Los Angeles aims to plant 90,000 more trees by the end of 2021, increasing the canopy cover in neglected areas. It isn't a panacea, and it's going to take a while to make a difference. But as temperatures warm, and as we grapple with the far more complicated solution of reducing greenhouse gases, planting trees equitably in all neighborhoods is a small but meaningful start.

Thank you for reading *National Geographic*. ▯

As Elliot Ross took photographs in Los Angeles, people using mass transit told him that the system's shelters provide too little shade and that waiting passengers can become dangerously overheated, even in winter. Verdant areas tend to be affluent ones in the city: Nearly 20 percent of the trees are in five census blocks—where one percent of the population resides.

ATEM Mini Pro model shown.

Introducing ATEM Mini Pro

The compact television studio that lets you create presentation videos and live streams!

Blackmagic Design is a leader in video for the television industry, and now you can create your own streaming videos with ATEM Mini. Simply connect HDMI cameras, computers or even microphones. Then push the buttons on the panel to switch video sources just like a professional broadcaster! You can even add titles, picture in picture overlays and mix audio! Then live stream to Zoom, Skype or YouTube!

Create Training and Educational Videos

ATEM Mini's includes everything you need. All the buttons are positioned on the front panel so it's very easy to learn. There are 4 HDMI video inputs for connecting cameras and computers, plus a USB output that looks like a webcam so you can connect to Zoom or Skype. ATEM Software Control for Mac and PC is also included, which allows access to more advanced "broadcast" features!

Use Professional Video Effects

ATEM Mini is really a professional broadcast switcher used by television stations. This means it has professional effects such as a DVE for picture in picture effects commonly used for commentating over a computer slide show. There are titles for presenter names, wipe effects for transitioning between sources and a green screen keyer for replacing backgrounds with graphics.

Live Stream Training and Conferences

The ATEM Mini Pro model has a built in hardware streaming engine for live streaming via its ethernet connection. This means you can live stream to YouTube, Facebook and Teams in much better quality and with perfectly smooth motion. You can even connect a hard disk or flash storage to the USB connection and record your stream for upload later!

Monitor all Video Inputs!

With so many cameras, computers and effects, things can get busy fast! The ATEM Mini Pro model features a "multiview" that lets you see all cameras, titles and program, plus streaming and recording status all on a single TV or monitor. There are even tally indicators to show when a camera is on air! Only ATEM Mini is a true professional television studio in a small compact design!

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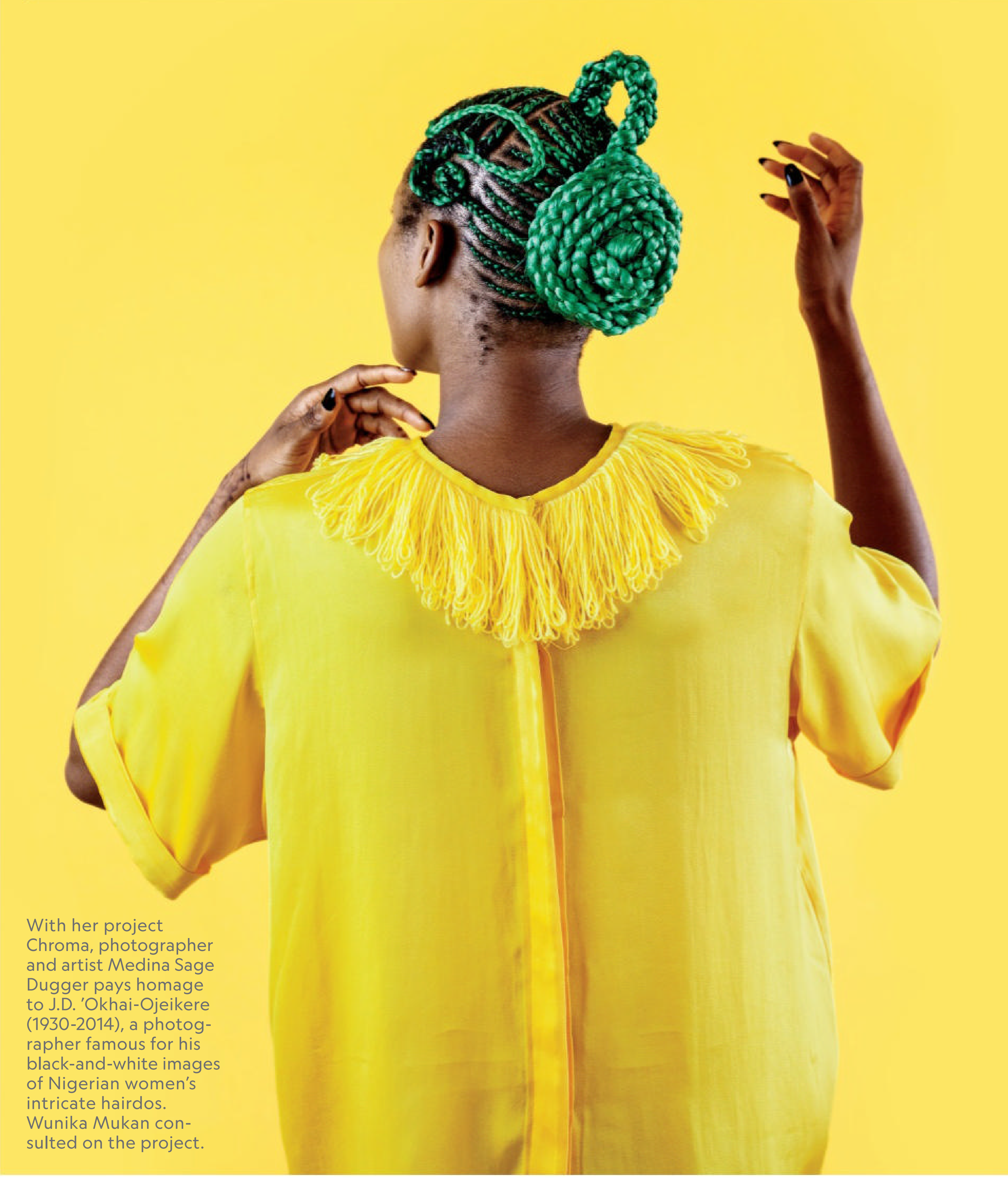
PHOTOGRAPHS BY **MEDINA SAGE DUGGER**

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE



With her project Chroma, photographer and artist Medina Sage Dugger pays homage to J.D. 'Okhai-Ojeikere (1930-2014), a photographer famous for his black-and-white images of Nigerian women's intricate hairdos. Wunika Mukan consulted on the project.

HOW HAIR PROCLAIMS CULTURE

There's meaning beyond the beauty of Nigerian hairstyles, as shown by photographers from two eras.

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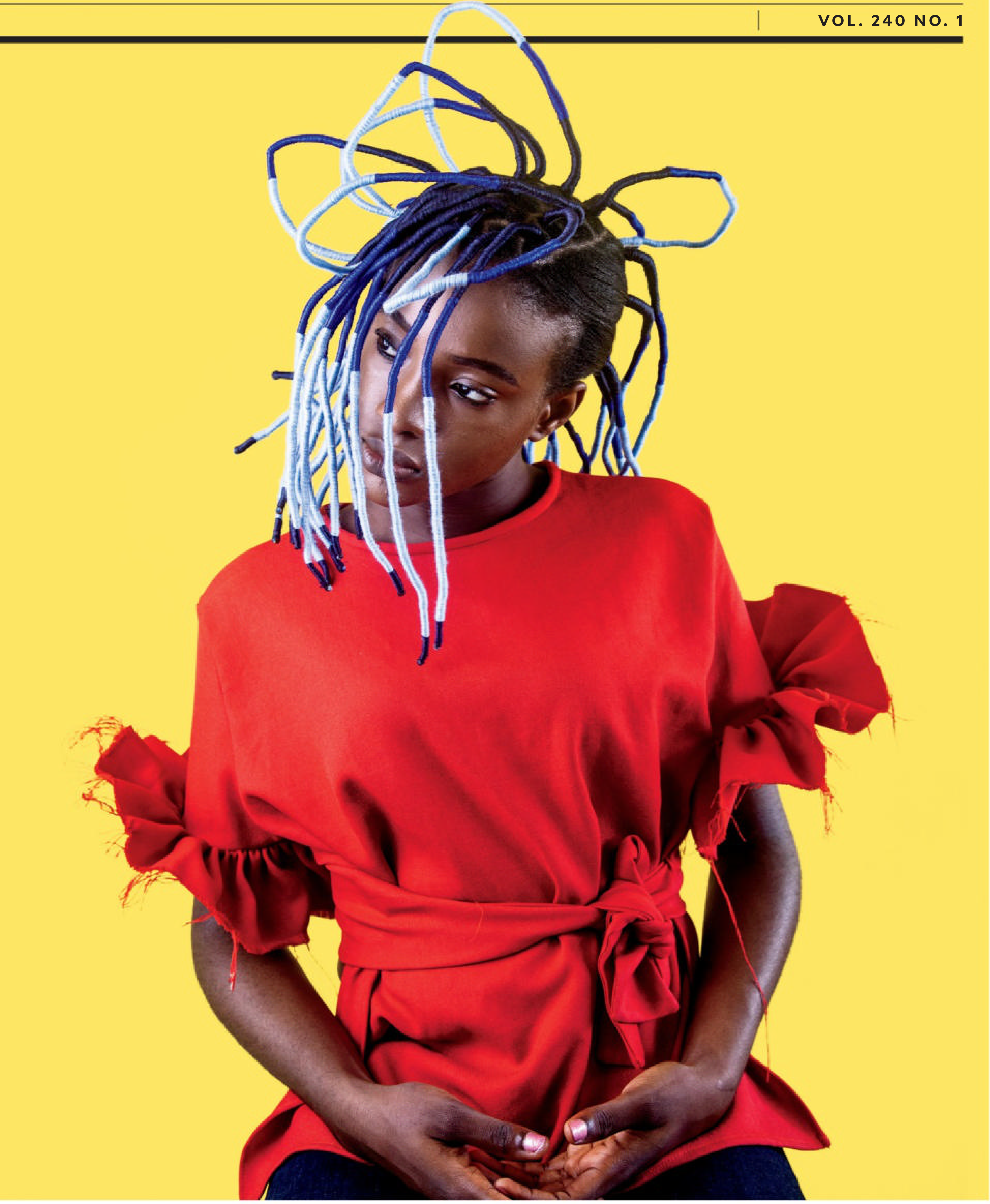
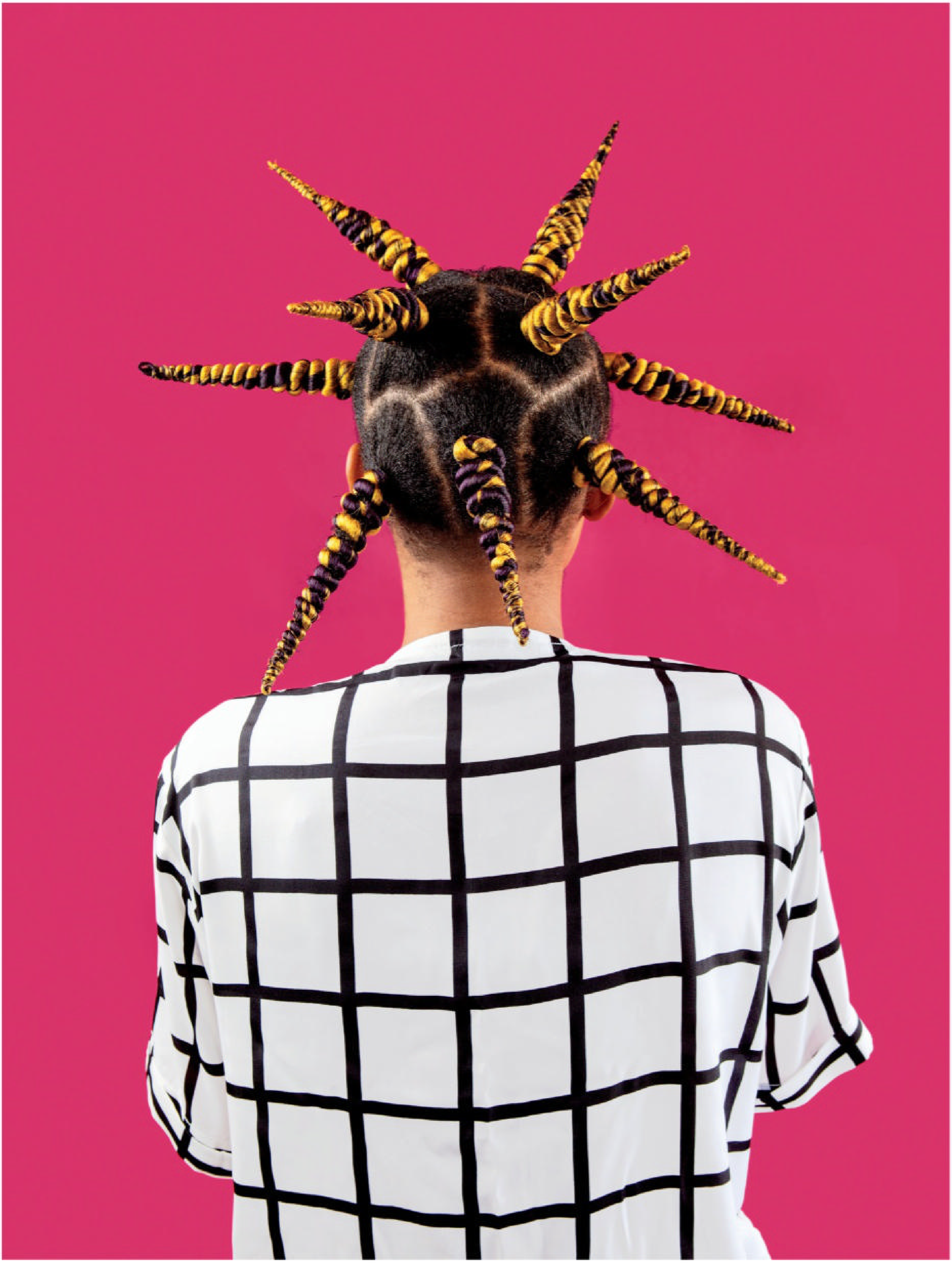
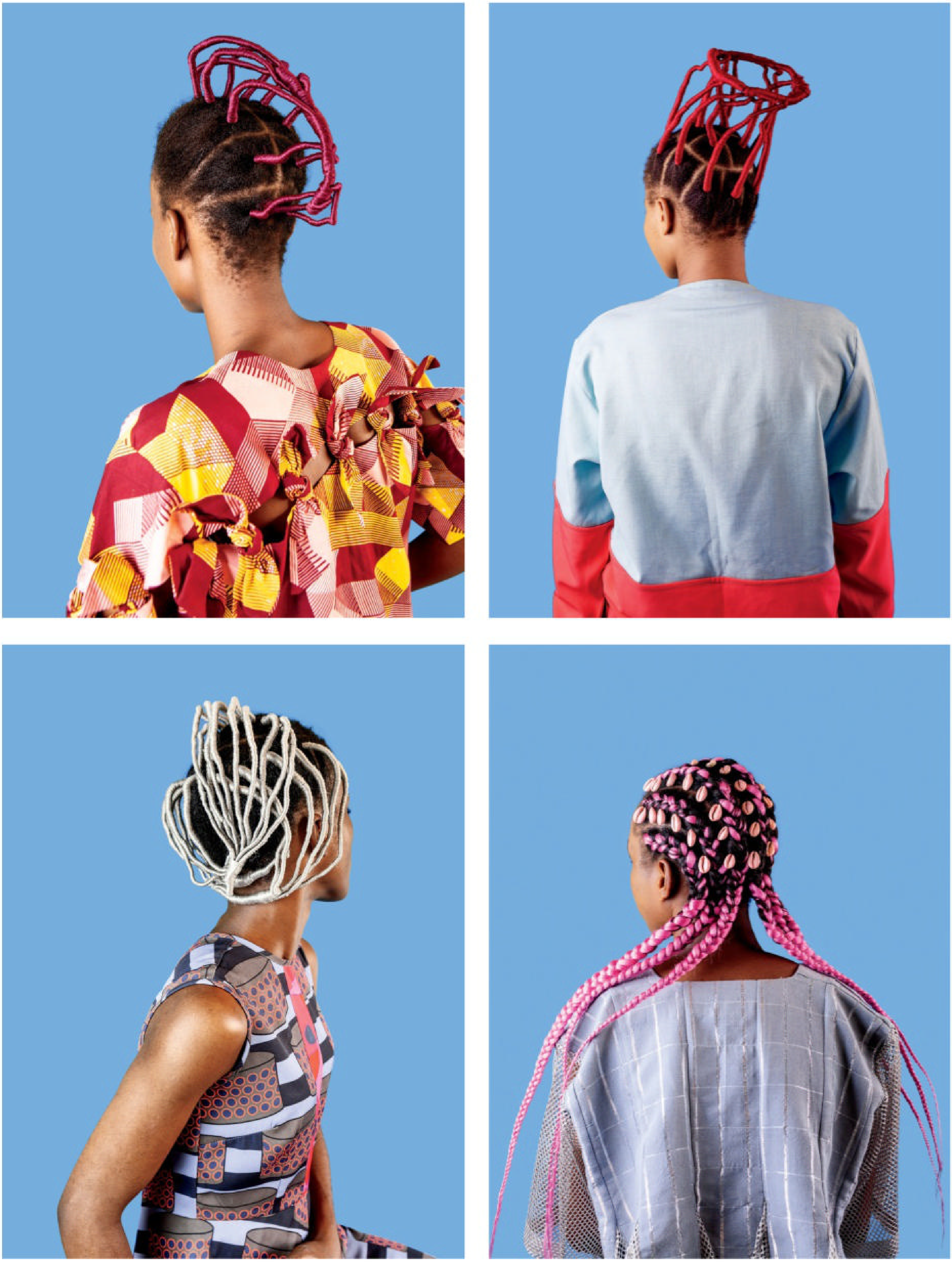
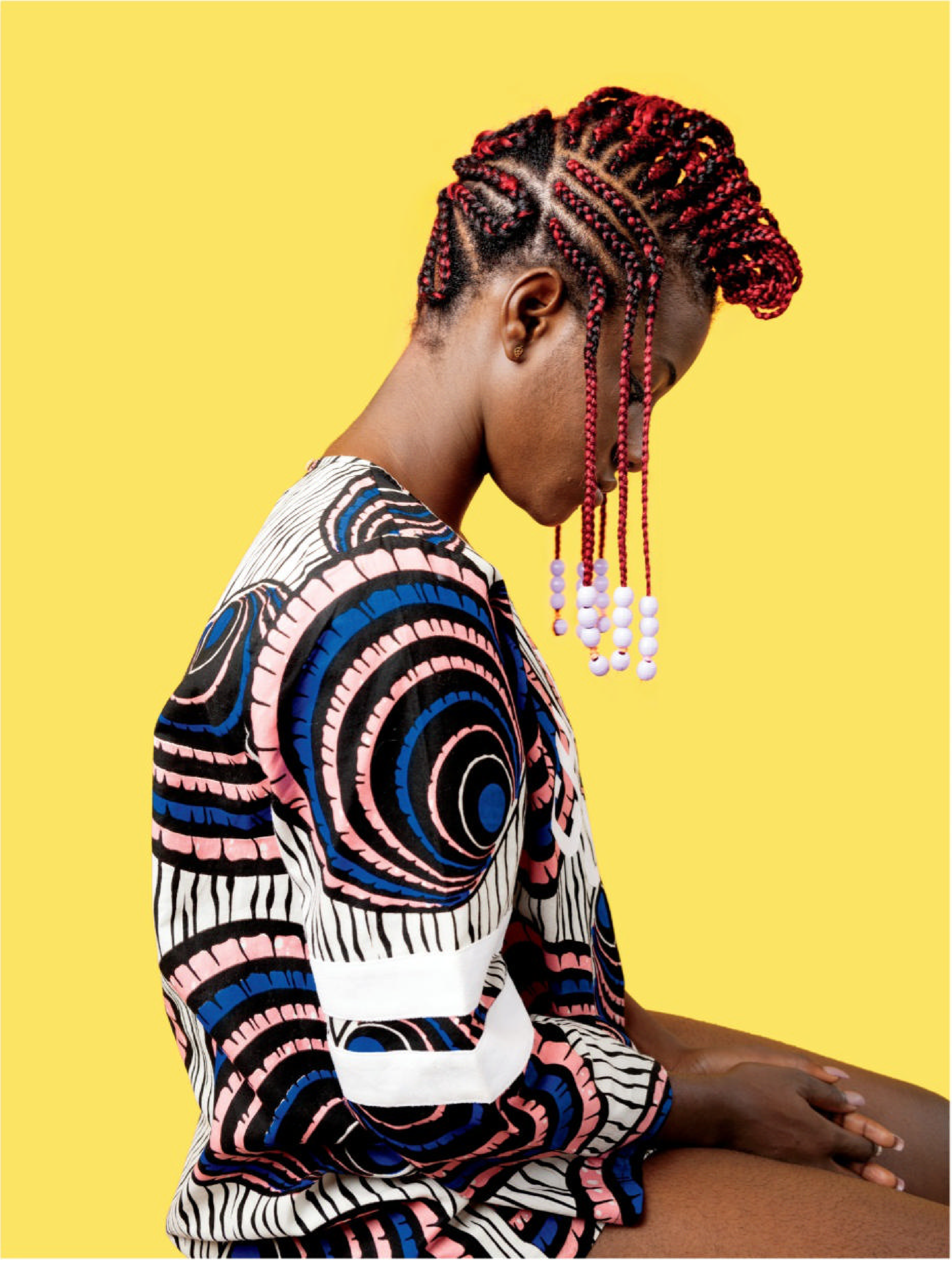




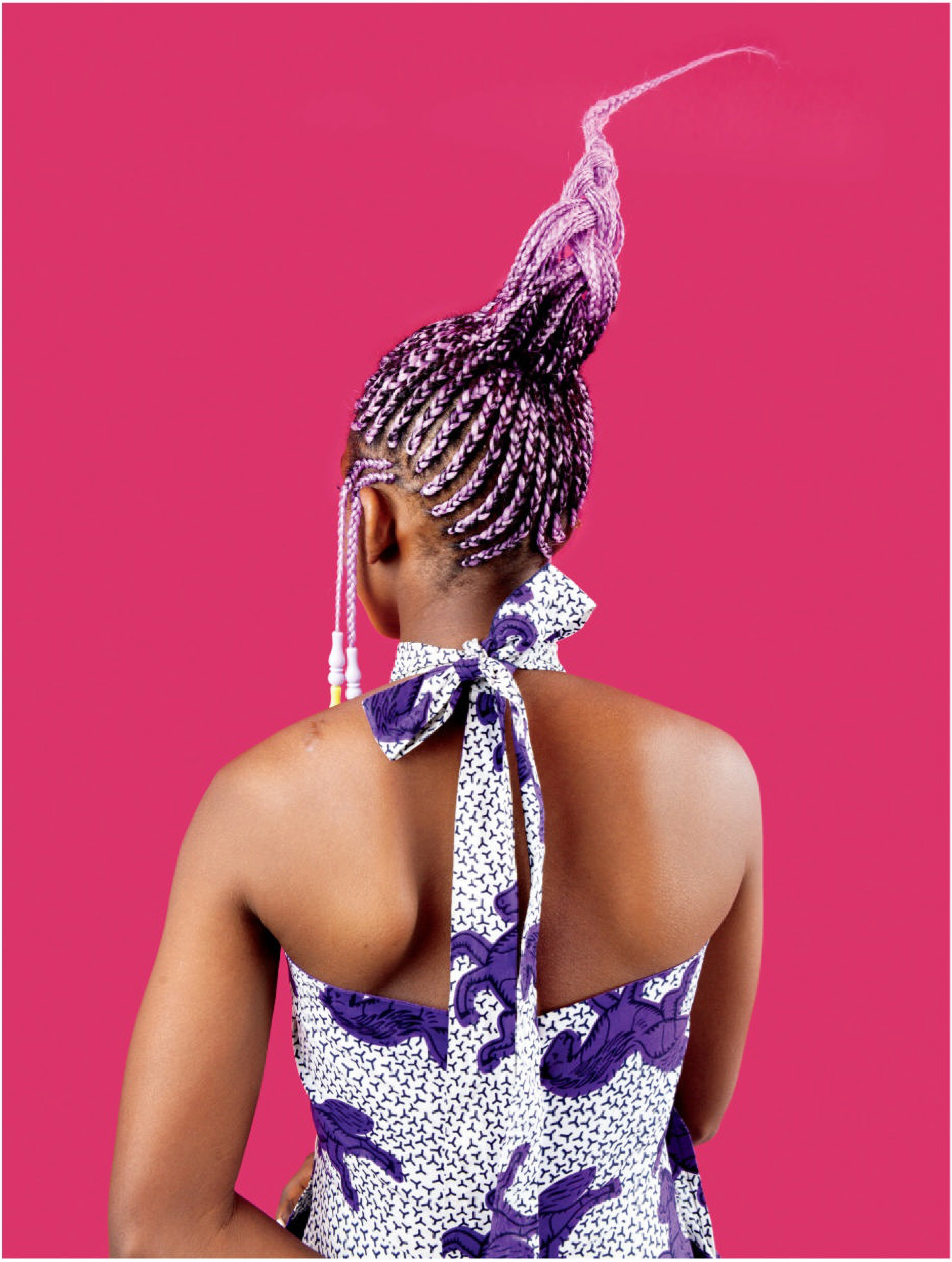
Nigerian women's expressive styles include flamboyant attire and accessories "and, amongst a younger, more daring set, colorful, showstopping hair," says writer Ayodeji Rotinwa.



The Chroma project models' hairstyles were created using colorful wool, weaves, hair spray, painted cowrie shells—and even the slender wooden sticks used for kebabs, for structure.



Dugger intends Chroma to celebrate pride in Nigerian identity through hair. Stylist Ijeoma Christopher drew on traditional braiding techniques as well as modern and futuristic styles, resisting the pull of uniformity.



Mindful that she saw the Chroma project with "a white outsider's gaze," Dugger partnered with Nigerians—including the project's hairstylists and models—in the decision-making and creative processes.

PROOF

THE BACKSTORY

PHOTOGRAPHERS CELEBRATE THE CULTURE AND HISTORY WOVEN INTO NIGERIA'S COMPLEX HAIRSTYLES.

IN THE WORK OF J.D. 'Okhai-Ojeikere (1930-2014), we see hair as storytelling. Over nearly half a century, the renowned photographer documented thousands of intricate, gravity-defying hairstyles that were the fashion in his native Nigeria after it won independence from the British Empire in 1960.

Before then, hairstyles were social markers symbolizing marital status, ethnic origins, socioeconomic class. With Nigerian independence, they took on political meaning too.

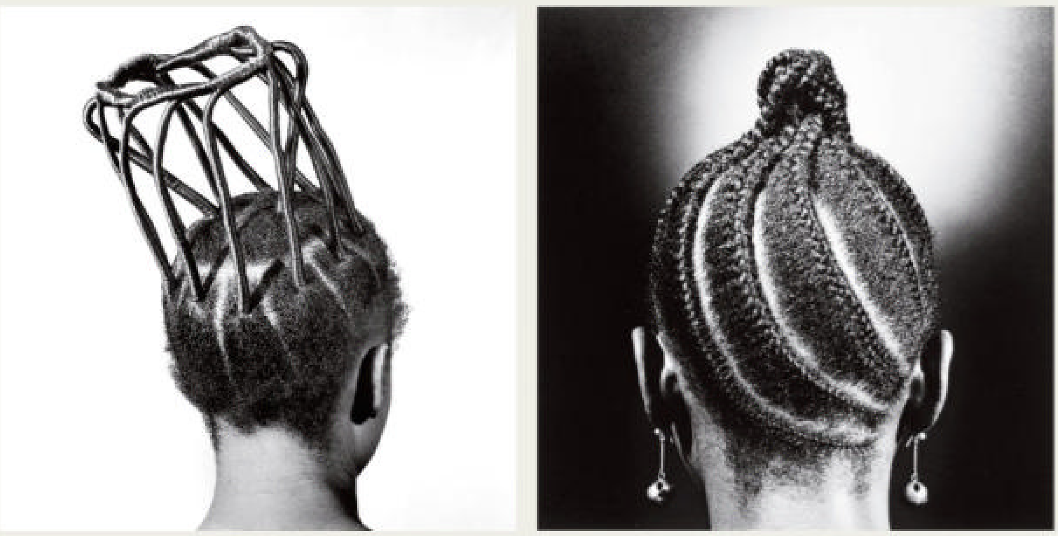
Ojeikere's work seems to have had a threefold purpose. He captured the resurgence of indigenous hairstyles that had fallen from favor under colonial powers. He documented hairstyle innovations as citizens reestablished their identity. And after a time, his approach became more archival, to preserve the memory of the styles in the face of globalization.

Photographer Medina Sage Dugger, a California native based in Lagos, launched her project in 2017, roughly 50 years after Ojeikere began his. Dugger's Chroma is an ode to Ojeikere and an attempt to build on his legacy. It borrows heavily from Ojeikere's vision but not his palette: His portraits are black-and-white, hers pop with color.

Today in Nigerian cities, globalization has fully taken root. Hairstyles are more decorative and less imbued with sociopolitical meaning—but still may make statements. As attitudes shift frequently between liberal and conservative (and more of the latter), the bold, whimsical hair that Dugger shows—even if it's only an individual fashion choice—can be seen as defiance of norms. "It is nice we can come together and unite," she says, and that "we can celebrate differences and pasts."

When Ojeikere began, his photographs were groundbreaking. Today we'd describe his work as traditional and Dugger's as modern. Yet with her new-hairstyle project, Dugger is continuing the tradition by documenting the culture as Ojeikere did. The storytelling goes on. —AYODEJI ROTINWA

Based in Lagos, Nigeria, and Accra, Ghana, **Ayodeji Rotinwa** covers cultural and artistic life and social justice issues.



Ojeikere photographed hairstyles notable for their patterns (right) or their messages. A style called *onile gogoro* (left) was a reference to the skyscrapers built in postindependence Nigeria.

J.D. 'OKHAI OJEIKERE, UNTITLED (ONILE GOGORO), 1975 (LEFT), AND UNTITLED (SUKU BANANA ONIDIDI), 1974, FROM THE SERIES HAIRSTYLES
COURTESY THE WALTHER COLLECTION AND GALERIE MAGNIN-A, PARIS

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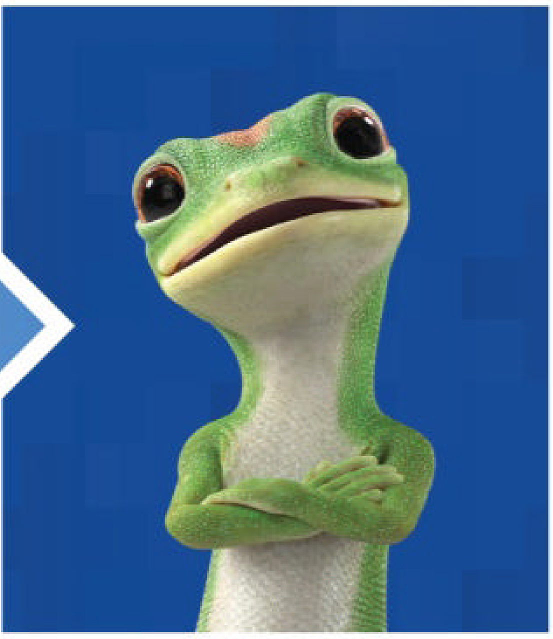

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ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY
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‘Honoring’ Health Care’s Bad Actors

THIS GROUP PRESENTS AWARDS FOR PRICE GOUGING, ETHICAL LAPSES, WASTEFUL PRACTICES, DYSFUNCTION—AND WISHES IT DIDN’T HAVE TO.

BY **JUDITH GARBER** AND **SHANNON BROWNLEE**

SIX MINUTES. THAT’S HOW LONG it took for Martin Shkreli to go from being just another CEO of a drug company to one of the most hated men in America. When Shkreli’s company, Turing Pharmaceuticals, bought the rights to the antiparasitic drug Daraprim in 2015, Turing promptly hiked the price from $13.50 a pill to a whopping $750—even though it costs only pennies to make. In a six-minute interview with CNBC, Shkreli justified the move by claiming his company would use the profits to invent new drugs. That’s when his smug non-apology, and his name, went viral.

Now, four years after Shkreli was convicted of securities fraud, America still loves to hate the “pharma bro.” But for all the attention Shkreli gets, he’s just one member of a large gallery of rogues from inside U.S. health care.

Practically every day there’s a news story about a bad actor taking advantage of vulnerable patients.

That may seem hard to believe given the kind of heroism we've all seen during COVID-19 as health-care workers put their own lives on the line to care for others. We all owe them a debt of gratitude. Unfortunately, for every person in our health-care system who has acted bravely, there is no shortage of selfish Shkrelis out there—like the hospital that used a technicality to force a nearly $900,000 medical bill on its own employee after a traumatic childbirth.

We should know. Each year at the Lown Institute, the staff combs through dozens of stories in the media, looking for examples of egregious profiteering and dysfunction in health care. With the help of a diverse panel of judges, we give out annual Shkreli Awards to 10 of the most deserving offenders.

Through the years, we've learned not to underestimate the lengths to which institutions and individuals will go to protect their bottom lines. We like to think that no bad behavior can surprise us anymore—but then we learn better. Last year, we found a pharmaceutical company seeking the financially advantageous "orphan" drug designation for a drug it said was for a rare disease. The disease was COVID-19.

When we put all the examples of Shkreli-like behavior together, they stop looking like anecdotes and start looking like evidence. That's the point of the awards: to highlight the structural weaknesses in health care that allow this kind of behavior to occur.

Again and again we see in the Shkreli Awards that the way that health care is paid for, regulated, and organized does not just permit profiteering, it encourages it. Private insurers pay hospitals at a much higher rate than Medicaid does, so hospitals often try to avoid taking Medicaid patients (who are usually the patients in greatest need of care). Our "fee-for-service" reimbursement system, in which doctors and hospitals are paid more to do more, gives a provider an incentive to recommend a procedure or test even when a patient doesn't need it. Drug prices have soared in recent years in part because Congress will not allow Medicare to negotiate for lower prices.

THE COVID-19 PANDEMIC revealed these structural problems as never before, making the 2020 Shkreli Award winners particularly shocking. Even as countless health-care workers and organizations stepped up, others treated the pandemic as "business as usual"—or worse, an opportunity for exploitation.

For example, several California hospitals with open ICU beds refused or delayed transfers of COVID-19 patients from nearby hospitals that were overflowing. The reason? The patients had Medicaid or were uninsured. Any sense that the hospitals should help relieve the overcrowding was outweighed by what's known inside health care as the "wallet biopsy"—a cynical phrase for how hospitals avoid caring for patients with public insurance.

Nor did COVID-19 melt the cold hearts of pharma. When the World Health Organization created an information-sharing project to more easily develop

'And the Shkreli Award Goes To…'

"…the worst examples of profiteering and dysfunction in health care." That's what the Lown Institute seeks for the sardonic awards it has bestowed since 2017. Not surprisingly, the 2020 "winners'" actions were all related to the COVID-19 pandemic.

1. Federal personal protective equipment task force gives lifesaving supplies to private companies to distribute, causing bidding wars and delays.

2. Drug company takes nearly a billion dollars in taxpayer funding to develop its COVID-19 vaccine, then sets highest price of any vaccinemaker.

3. Hospitals with extra beds refuse to take uninsured patients from neighboring hospitals that are overrun.

4. Nursing homes fail to protect vulnerable Americans from COVID-19.

5. Pharma firms compete for profit instead of cooperating on COVID-19.

6. Hospital CEO pens op-ed justifying high vaccine prices; neglects to disclose $487,500 received in stock options and other compensation as a Moderna board member.

7. Hospitals punish clinicians for wearing masks and speaking out on COVID-19 safety issues.

8. Connecticut doctor uses town's COVID-19 testing sites to bilk residents.

9. Pandemic profiteers peddle fake and potentially harmful COVID-19 "cures."

10. Private equity–backed companies spend millions to protect surprise billing while cutting physician pay and pocketing relief dollars. —JG AND SB

ILLUSTRATION BY EIKO OJALA

and distribute COVID-19 resources, several large pharmaceutical companies that were developing vaccines refused to participate. One CEO went so far as to call the project “nonsense” and “dangerous.”

Others took the pandemic as an opportunity to maximize their profit at public expense. One New England doctor allegedly used a public COVID-19 testing site to test for at least 20 other respiratory pathogens. Why just test for COVID-19 when you can do a “super COVID test” and bill insurers up to $2,000?

These examples illustrate an important lesson we’ve learned: What Shkreli Award recipients do is certainly unethical, but usually it is not illegal. Martin Shkreli may have said it best in an interview with *Vanity Fair* magazine: “I liken myself to the robber barons. Rockefeller made no attempt to apologize as long as what he was doing was legal.” (Ironically, when Shkreli went to prison, it was not for his price gouging but for cheating a hedge fund.) His conviction and incarceration didn’t bring down Daraprim’s price; it’s still hundreds of dollars per tablet.

The story of Martin Shkreli, and most Shkreli Award winners, is a story of systemic—and not necessarily individual—failure. Some say our health system is broken, but that’s not quite right. One aspect of the system is working exactly as intended: to make a few people a heck of a lot of money.

WHEN WE ANNOUNCED the 2020 awards, one of our judges, pediatrician and Flint water crisis whistleblower Mona Hanna-Attisha, posed this question: “What can we do to make this the last Shkreli Awards?” As much as we’ve learned from this project, we’d like nothing more than to retire it for lack of nominees. But that will take some serious changes.

If the Biden administration and Congress want to put us out of a job, they need to make these ethical lapses illegal and then prosecute them. There should be limits on price increases for health-care services and drugs (especially for essential medicines like Daraprim). We need Medicare and other government payers to be able to negotiate prices down in exchange for the huge volume of patients they cover.

The way we pay hospitals and physicians must be restructured so that anyone, regardless of income or insurance status, can access the same high-quality care. Some policy experts have proposed an “all-payer rate setting” system in which all insurers, public and private, pay the same amount for a given medical service. No more discriminating against poor patients with Medicaid or against older patients with Medicare. And the Biden administration should continue moving toward implementing so-called value-based payments—giving hospitals set budgets and physicians’ salaries—rather than fee-for-service payments that encourage harmful unnecessary care.

WE BELIEVE A RADICALLY BETTER HEALTH-CARE SYSTEM IS POSSIBLE, BUT WE CAN’T GET THERE BY BEING SHY ABOUT CALLING OUT BAD BEHAVIOR.

Even if you’re not a policymaker, you can still make a difference. Several Shkreli Award recipients have changed their ways because grassroots movements of clinicians, patients, and activists put pressure on them. For example, the Free the Vaccine movement contributed to biotech company Moderna lowering the price of its COVID vaccine (which had been the highest of any), and public outcry from doctors led at least one Shkreli Award winner who failed to disclose financial conflicts of interest to resign from her position.

We’d be remiss not to acknowledge the importance of independent journalism in holding health-care actors accountable. The Shkreli Awards would not be possible without the courageous reporters who root out and write about these wrongdoings.

Despite all we’ve seen, we’re not pessimistic. We believe a radically better health-care system is possible, but we can’t get there by being shy about calling out bad behavior. As our founder, physician Bernard Lown (see below), said, “Those who see the invisible can do the impossible.” The Shkreli Awards have helped to illuminate aspects of health care that have remained hidden for too long. We hope that by uncovering them, we support the creation of a truly equitable and healing health system. □

At the Lown Institute, a Massachusetts-based think tank that advocates for improvement in the U.S. health system, **Judith Garber** is health policy and communications fellow and **Shannon Brownlee** is special adviser to the president.

LOWN LEGACY

Physician Bernard Lown (1921-2021) was known to call out malfeasance in health care when he saw it—as his namesake institute does today. But the pioneering cardiologist and humanitarian was known for much more. He was co-inventor of the defibrillator and created one of the first coronary care units. He spoke against nuclear proliferation, cofounded the International Physicians for the Prevention of Nuclear War, and received a Nobel Peace Prize on that group’s behalf in 1985.

PHOTO: LOWN INSTITUTE

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DISPATCHES
FROM THE FRONT LINES
OF SCIENCE
AND INNOVATION

Off with its head. Or body. Scientists in Japan have discovered that two species of sea slugs can rip off their heads and regenerate new bodies, organs and all, in less than a month. Scientists theorize that the slugs, *Elysia marginata* and *Elysia atroviridis*, do this to rid themselves of internal parasites. —AR

OCEAN LIFE

Deep down, sharks glow in the dark

Scientists studying deep-sea life off the New Zealand coast identified three species of sharks that are bioluminescent—that is, they glow in the dark. These species—the blackbelly lanternshark, southern lanternshark, and kitefin shark (right)—produce a soft blue-green light using specialized cells in their skin. The kitefin shark, at nearly six feet long, is one of Earth's largest animals capable of emitting light.

The find is a reminder of "how much we still have to discover and understand about the deep ocean and its inhabitants," says biologist Diva Amon, a National Geographic emerging explorer. More research is needed on how common bioluminescence is among deep-sea sharks, and how they employ it. Scientists suspect that the sharks, by making their bellies glow, can hide their silhouette from predators lurking in deeper, darker waters—a trick known as counterillumination. —ANNIE ROTH

National Geographic's SharkFest celebrates the ocean's apex predators in July. Watch *Shark Beach With Chris Hemsworth* and other shark-infested programming on the network, and the feature documentary *Playing With Sharks* streaming on Disney+.

PLANTING TREES

SEEDLINGS NEEDED TO HIT 2030 GOAL

The United States has pledged to help the world plant and protect a trillion trees by 2030, but the plan has hit a snag: There aren't enough seedlings to grow into trees for planting—not by a long shot, a new study says. At least three billion tiny trees a year are needed to plant available acres—a 130 percent planting jump that would add tens of billions of dollars in costs for seed collection, infrastructure, and more. The new trees also would need long-term monitoring to ensure they survive pressures such as pests, disease, drought, and fire. Environmentalists say that planting that many trees, and conserving mature ones, is vital to remove planet-warming carbon dioxide from the atmosphere, helping cool a warming future. —KYLA MANDEL

PHOTOS: JÉRÔME MALLEFET, FNRS, UNIVERSITÉ CATHOLIQUE DE LOUVAIN (SHARK); SAYAKA MITOH (SEA SLUG); CHIP SOMODEVILLA, GETTY IMAGES (SEEDLING)

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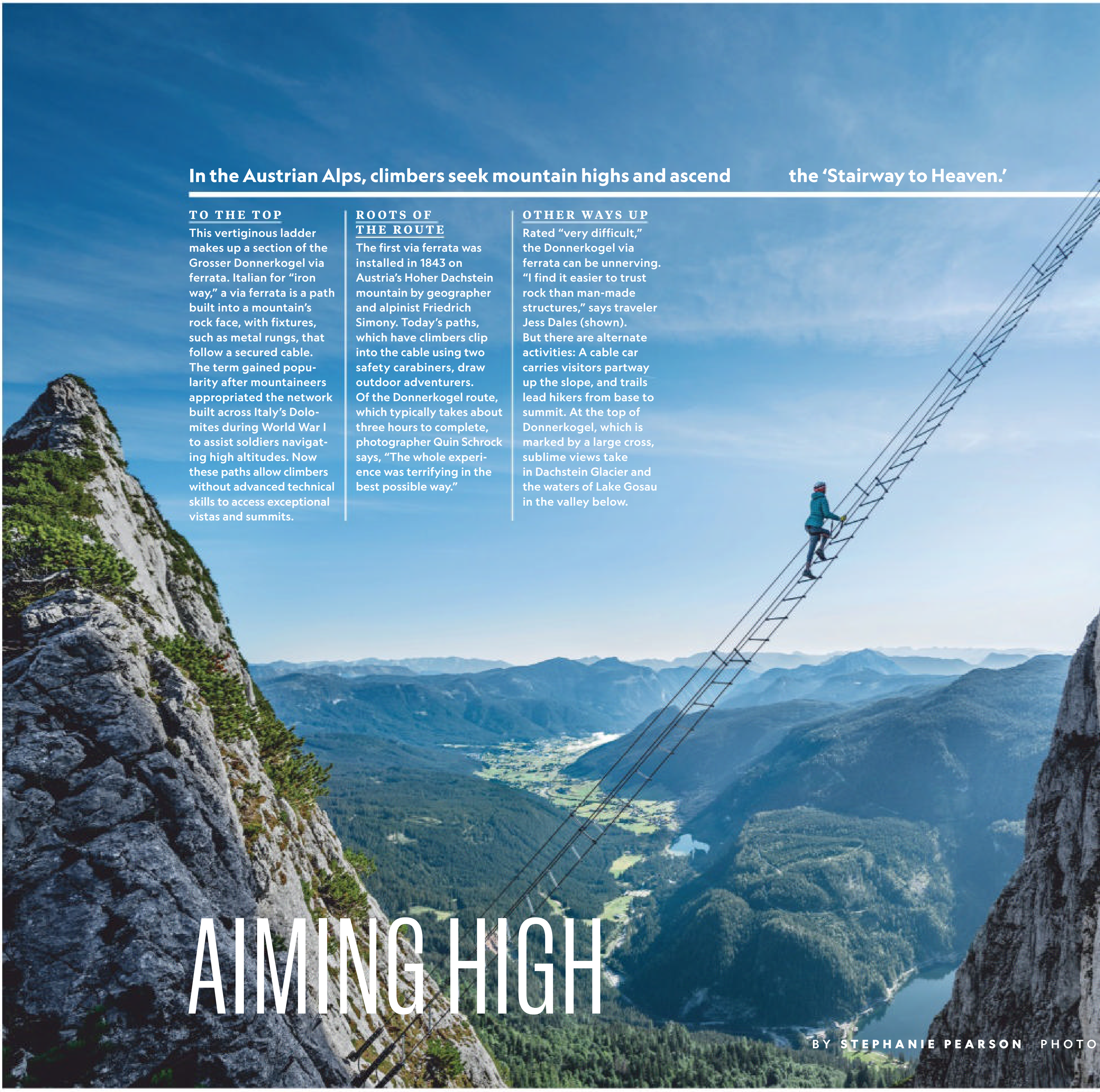


AIMING HIGH

In the Austrian Alps, climbers seek mountain highs and ascend the 'Stairway to Heaven.'

BY STEPHANIE PEARSON PHOTO

TO THE TOP

This vertiginous ladder makes up a section of the Grosser Donnerkogel via ferrata. Italian for "iron way," a via ferrata is a path built into a mountain's rock face, with fixtures, such as metal rungs, that follow a secured cable. The term gained popularity after mountaineers appropriated the network built across Italy's Dolomites during World War I to assist soldiers navigating high altitudes. Now these paths allow climbers without advanced technical skills to access exceptional vistas and summits.

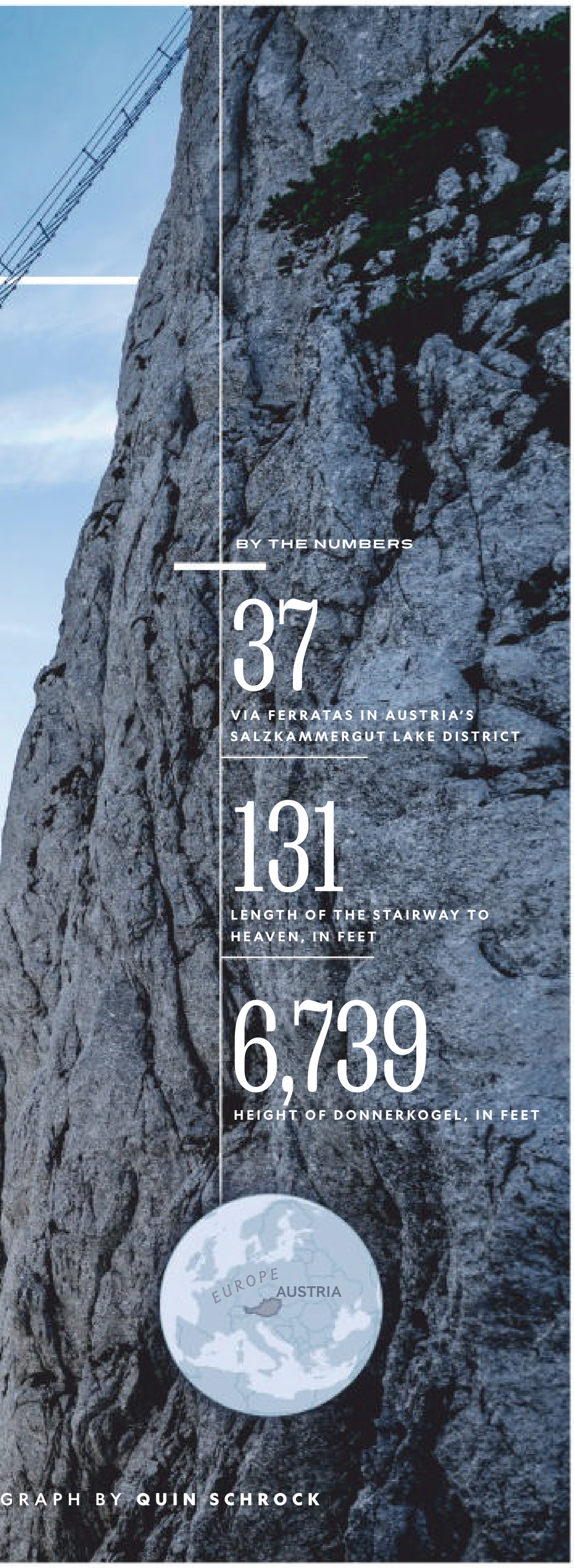
ROOTS OF THE ROUTE

The first via ferrata was installed in 1843 on Austria's Hoher Dachstein mountain by geographer and alpinist Friedrich Simony. Today's paths, which have climbers clip into the cable using two safety carabiners, draw outdoor adventurers. Of the Donnerkogel route, which typically takes about three hours to complete, photographer Quin Schrock says, "The whole experience was terrifying in the best possible way."

OTHER WAYS UP

Rated "very difficult," the Donnerkogel via ferrata can be unnerving. "I find it easier to trust rock than man-made structures," says traveler Jess Dales (shown). But there are alternate activities: A cable car carries visitors partway up the slope, and trails lead hikers from base to summit. At the top of Donnerkogel, which is marked by a large cross, sublime views take in Dachstein Glacier and the waters of Lake Gosau in the valley below.

NGM MAPS



BY THE NUMBERS

37

VIA FERRATAS IN AUSTRIA'S SALZKAMMERGUT LAKE DISTRICT

131

LENGTH OF THE STAIRWAY TO HEAVEN, IN FEET

6,739

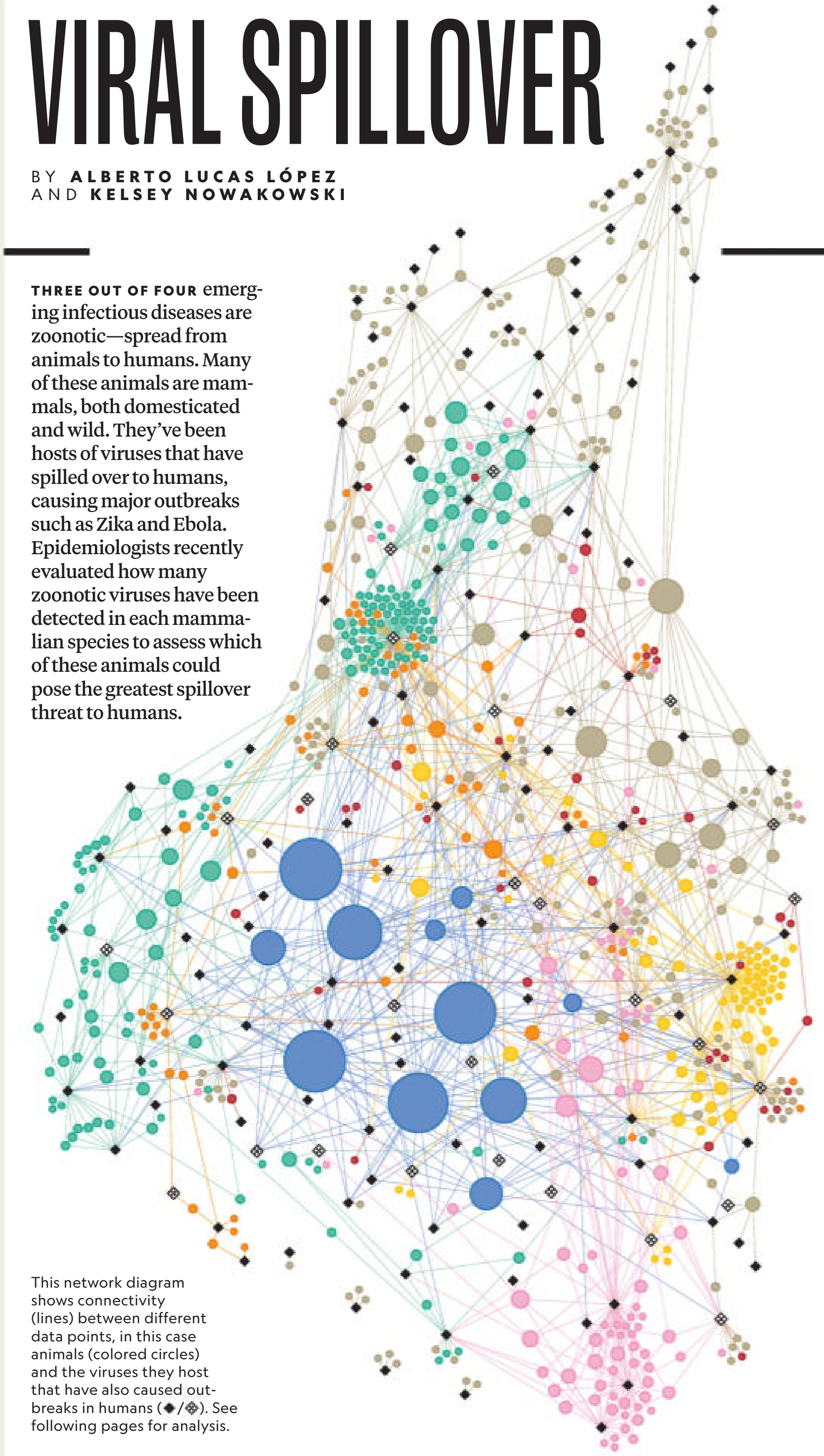
HEIGHT OF DONNERKOGEL, IN FEET

GRAPH BY QUIN SCHROCK

VIRAL SPILLOVER

BY **ALBERTO LUCAS LÓPEZ**
AND **KELSEY NOWAKOWSKI**

THREE OUT OF FOUR emerging infectious diseases are zoonotic—spread from animals to humans. Many of these animals are mammals, both domesticated and wild. They've been hosts of viruses that have spilled over to humans, causing major outbreaks such as Zika and Ebola. Epidemiologists recently evaluated how many zoonotic viruses have been detected in each mammalian species to assess which of these animals could pose the greatest spillover threat to humans.



This network diagram shows connectivity (lines) between different data points, in this case animals (colored circles) and the viruses they host that have also caused outbreaks in humans (◆/◈). See following pages for analysis.

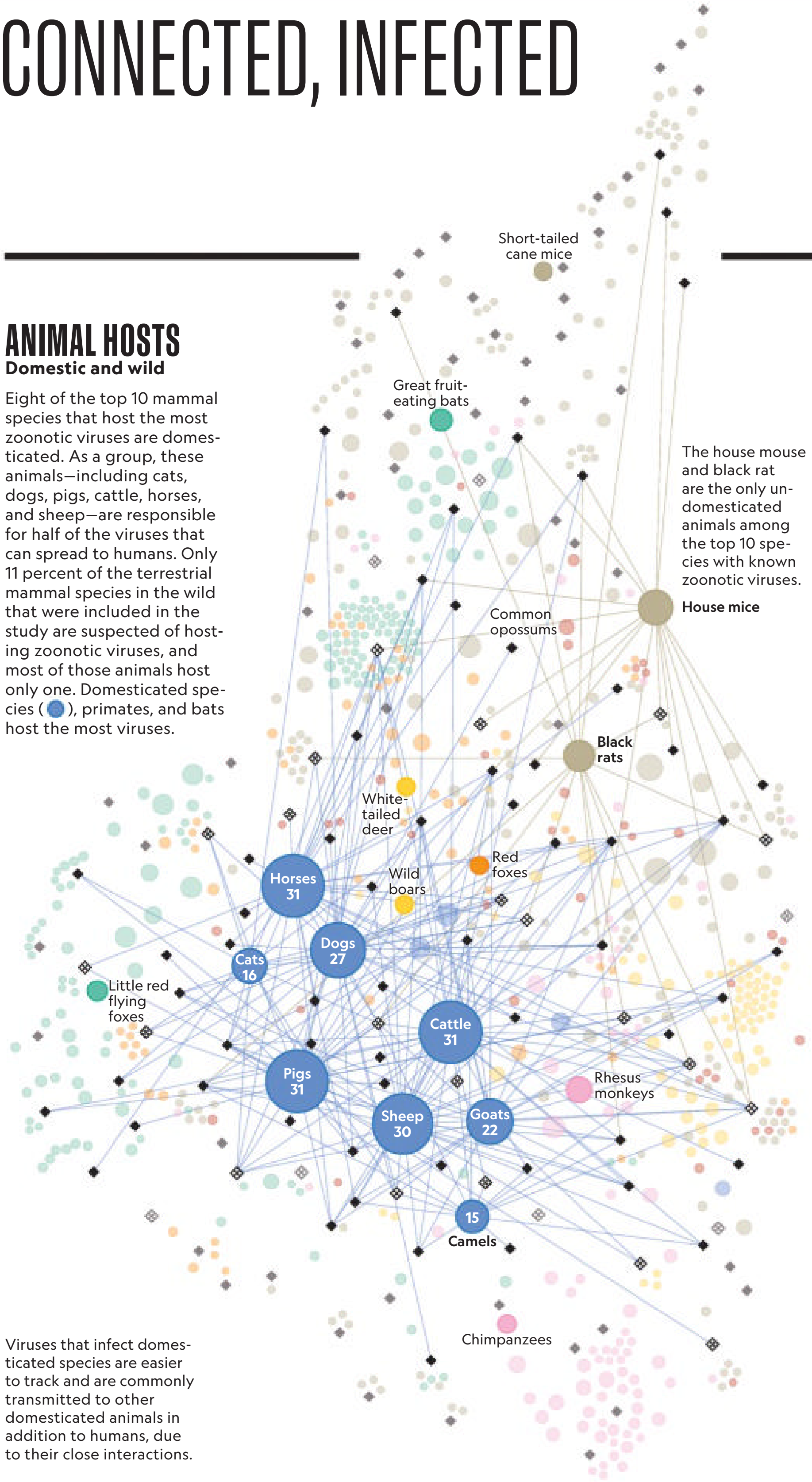
CONNECTED, INFECTED

Spillover risk is highest in abundant, domesticated animals or in common wildlife species that have adapted to human environments. This research was conducted before the COVID-19 pandemic, but experts suspect that SARS-CoV-2 originated in an animal before jumping to humans. All the zoonotic viruses below have caused at least one outbreak among humans. Outbreaks are often underreported.

ANIMAL HOSTS

Domestic and wild

Eight of the top 10 mammal species that host the most zoonotic viruses are domesticated. As a group, these animals—including cats, dogs, pigs, cattle, horses, and sheep—are responsible for half of the viruses that can spread to humans. Only 11 percent of the terrestrial mammal species in the wild that were included in the study are suspected of hosting zoonotic viruses, and most of those animals host only one. Domesticated species (●), primates, and bats host the most viruses.



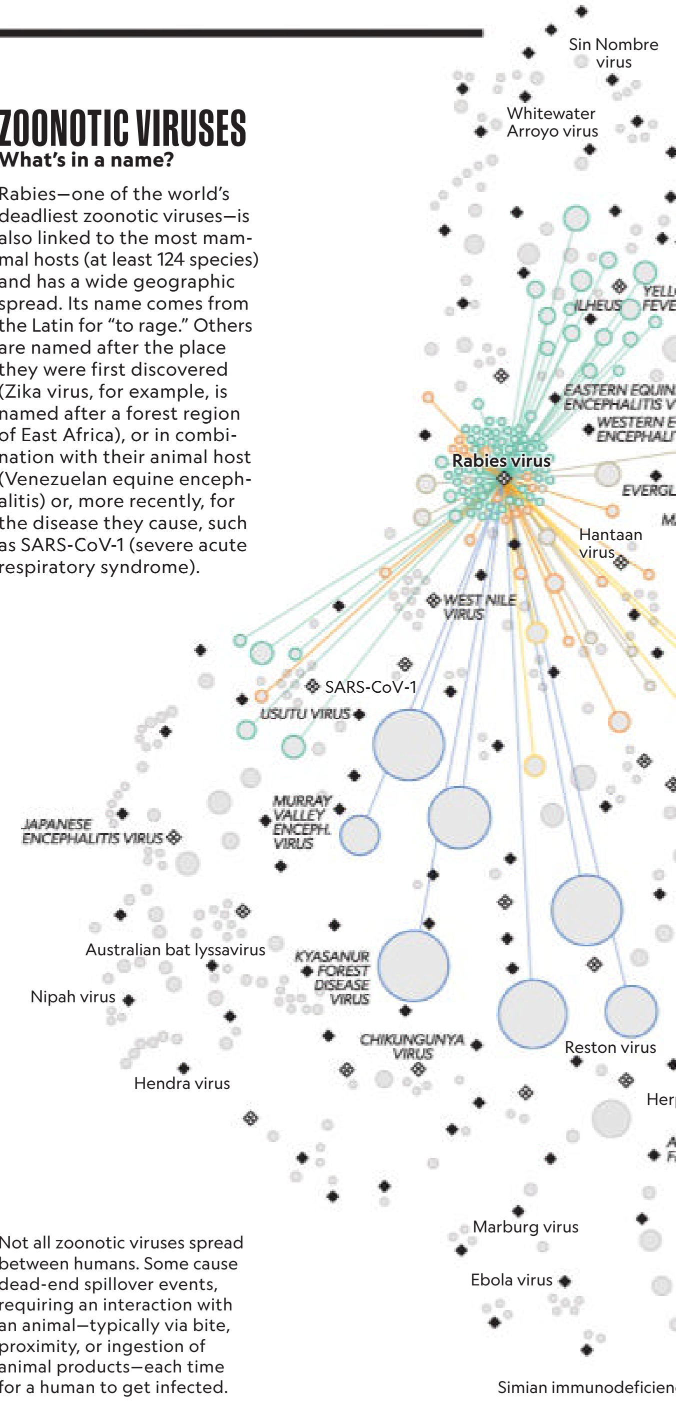
The house mouse and black rat are the only undomesticated animals among the top 10 species with known zoonotic viruses.

Viruses that infect domesticated species are easier to track and are commonly transmitted to other domesticated animals in addition to humans, due to their close interactions.

ZOONOTIC VIRUSES

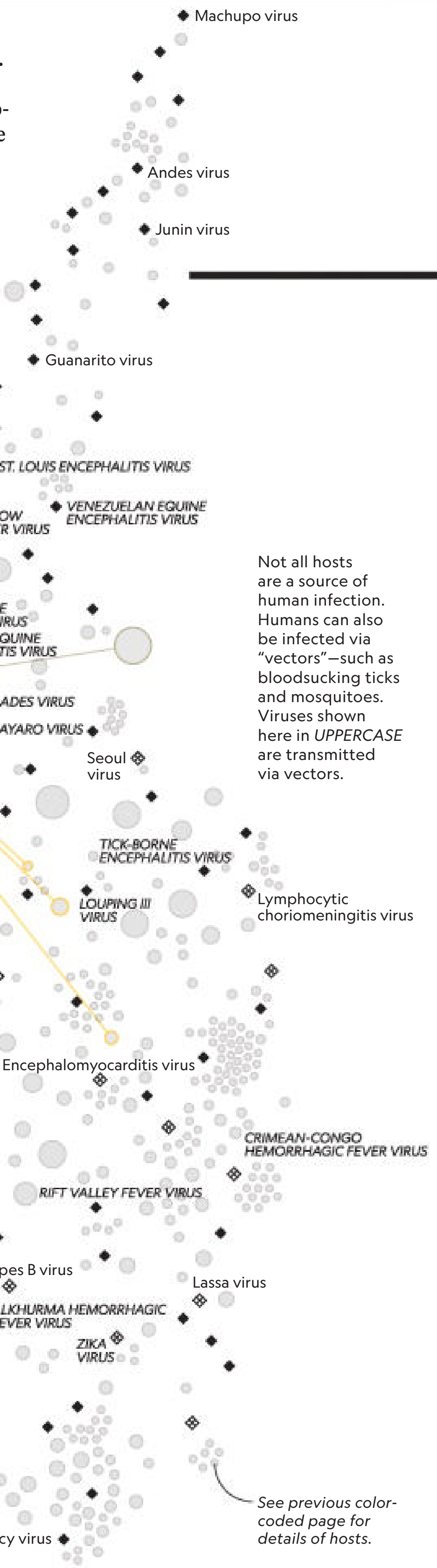
What's in a name?

Rabies—one of the world's deadliest zoonotic viruses—is also linked to the most mammal hosts (at least 124 species) and has a wide geographic spread. Its name comes from the Latin for "to rage." Others are named after the place they were first discovered (Zika virus, for example, is named after a forest region of East Africa), or in combination with their animal host (Venezuelan equine encephalitis) or, more recently, for the disease they cause, such as SARS-CoV-1 (severe acute respiratory syndrome).



Not all zoonotic viruses spread between humans. Some cause dead-end spillover events, requiring an interaction with an animal—typically via bite, proximity, or ingestion of animal products—each time for a human to get infected.

SOURCES: CHRISTINE K. JOHNSON, PETA L. HITCHENS, PRANAV S. PANDIT, JULIE RUSHMORE, TIERRA SMILEY EVANS, CRISTIN C.W. YOUNG, AND MEGAN M. DOYLE, "GLOBAL SHIFTS IN MAMMALIAN POPULATION TRENDS REVEAL KEY PREDICTORS OF VIRUS SPILLOVER RISK," *PROCEEDINGS OF THE ROYAL SOCIETY B*; CDC; WHO



Not all hosts are a source of human infection. Humans can also be infected via "vectors"—such as bloodsucking ticks and mosquitoes. Viruses shown here in *UPPERCASE* are transmitted via vectors.

See previous color-coded page for details of hosts.

These diagrams show the wild and domesticated mammalian species (colored circles) that are known to host at least one zoonotic virus. Host species are linked by harboring shared zoonotic viruses (◆/❖). Exactly how domesticated animals get these viruses is often unclear, but it's probable that wild mammals were the original hosts for most zoonotic viruses found in domestic mammals and humans.

Mammalian viruses that can pass to humans

◆ Limited geographic spread
❖ Broad geographic spread*

Mammalian animal hosts. Circle size is relative to "virus richness," the number of zoonotic viruses calculated to occur in that species.

● Domestic animals
● Rodents
● Bats
● Ungulates
● Primates
● Carnivores
● Other wildlife species

RISING RISK

Threatened hosts

Opportunities for pathogen spillover multiply when humans exploit wildlife or alter natural habitats through encroachment and development. These activities increase the probability of human-wildlife interactions that facilitate virus transmission.

Threatened species with a reduction in population size due to:

human exploitation by hunting, trade, and habitat encroachment and destruction, such as ● chimpanzee, ● Madagascan flying fox, ● stump-tailed macaque, ● Owston's palm civet, or ● Asian buffalo, have...

declines in ecosystem extent and habitat quality, such as ● gray-headed flying fox, ● mandrill, ● southern pig-tailed macaque, ● European ground squirrel, or ● fossa, have...

...twice as many zoonotic viruses (◆/❖) as those **threatened for other reasons.**

GLOBAL ORIGINS

First outbreaks

Several recent epidemics caused by zoonotic viruses, such as SARS and Ebola, originated in Asia and Africa, respectively, but first reports of animal-to-human transmissions have been documented around the world.

Sin Nombre (N. America)

In May 1993 an unexplained pulmonary illness killed a young Navajo man in the U.S. Additional cases were soon reported, and the deer mouse was identified as the primary host.

SARS (East Asia)

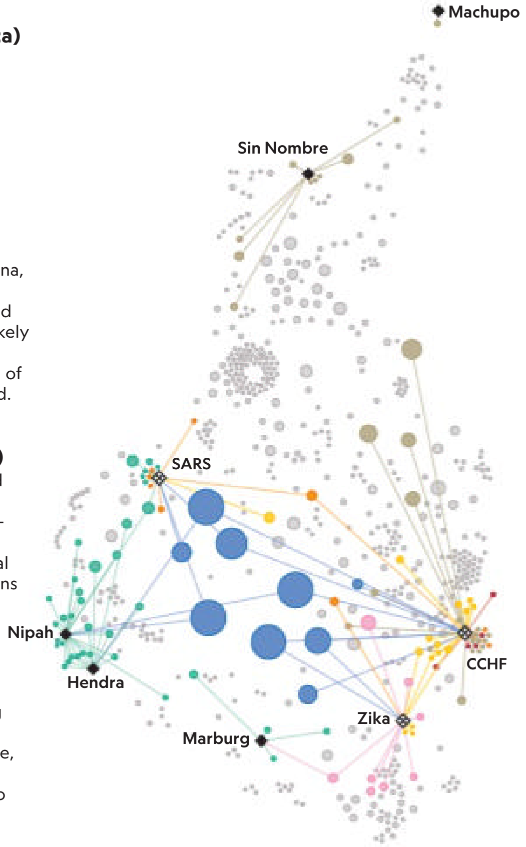
First detected in 2003 in China, the virus spread to over 24 countries in Asia, Europe, and the Americas. Bats are the likely original hosts; thousands of captive civet cats suspected of carrying the virus were killed.

Nipah (Southeast Asia)

This virus was first identified in a 1999 outbreak among pig farmers in Malaysia. Bangladesh has had outbreaks since 2001. Bats are the initial source of infection for humans and other mammals.

Hendra (Oceania)

Two humans and 21 racehorses were infected during the first known outbreak in Hendra, a suburb of Brisbane, Australia, in 1994. The virus can spread from fruit bats to horses and then to people.



Machupo (S. America)

Also known as Bolivian hemorrhagic fever virus, it emerged in Bolivia in 1952 among farmers. The reservoir host is the large vesper mouse, a forest rodent that also favors human habitats.

CCHF (Europe)

Crimean-Congo hemorrhagic fever first broke out in Crimea (1944) and was later identified in the Belgian Congo (1956). Many mammals host the virus, but ticks are the main source of human infections.

Zika (East Africa)

Scientists discovered the virus in a research monkey in Uganda in 1947, and soon after in mosquitoes. Sporadic human cases occurred for decades before it spread globally.

Marburg (Africa)

It originated in Africa but is named for the German city where it was first identified. In 1967 scientists became ill after working with African green monkey tissue; the African fruit bat is the host.

---

*VIRUSES PRESENT IN FOUR OR MORE WORLD HEALTH ORGANIZATION REGIONS; ONLY VIRUSES WITH PUBLISHED DATA ON SUSPECTED ANIMAL HOSTS ARE INCLUDED. INVESTIGATIONS INTO HOSTS WITH GREATEST SPILLOVER RISK ARE HAMPERED BY SPARSE DATA.

Enjoying the outdoors shouldn't imperil the Earth. Give Mother Nature a summer break with easy-on-the-environment ideas.

PLANET POSSIBLE

For more stories about how to help the planet, go to *natgeo.com/planet*

BY **CHRISTINA NUNEZ**

1. SMART SUNGLASSES

Made into shades

It's estimated that discarded fishing gear accounts for more than half the total weight of plastics floating in the ocean. Search online for "recycled sunglasses" and you'll find several options made from recovered ocean debris, including "ghost" fishing nets that were lost or abandoned.

2. REEF-SAFE SCREEN

Block out toxins

Protect your skin and marine life at the same time. Avoid sunscreen ingredients such as oxybenzone and octinoxate. When they end up in water, they can harm corals and other ocean dwellers. More ideas: Seek shade—and find additional guidance at *oceanservice.noaa.gov/sunscreen*.

3. EATING OUT(DOORS)

Dishware from plants

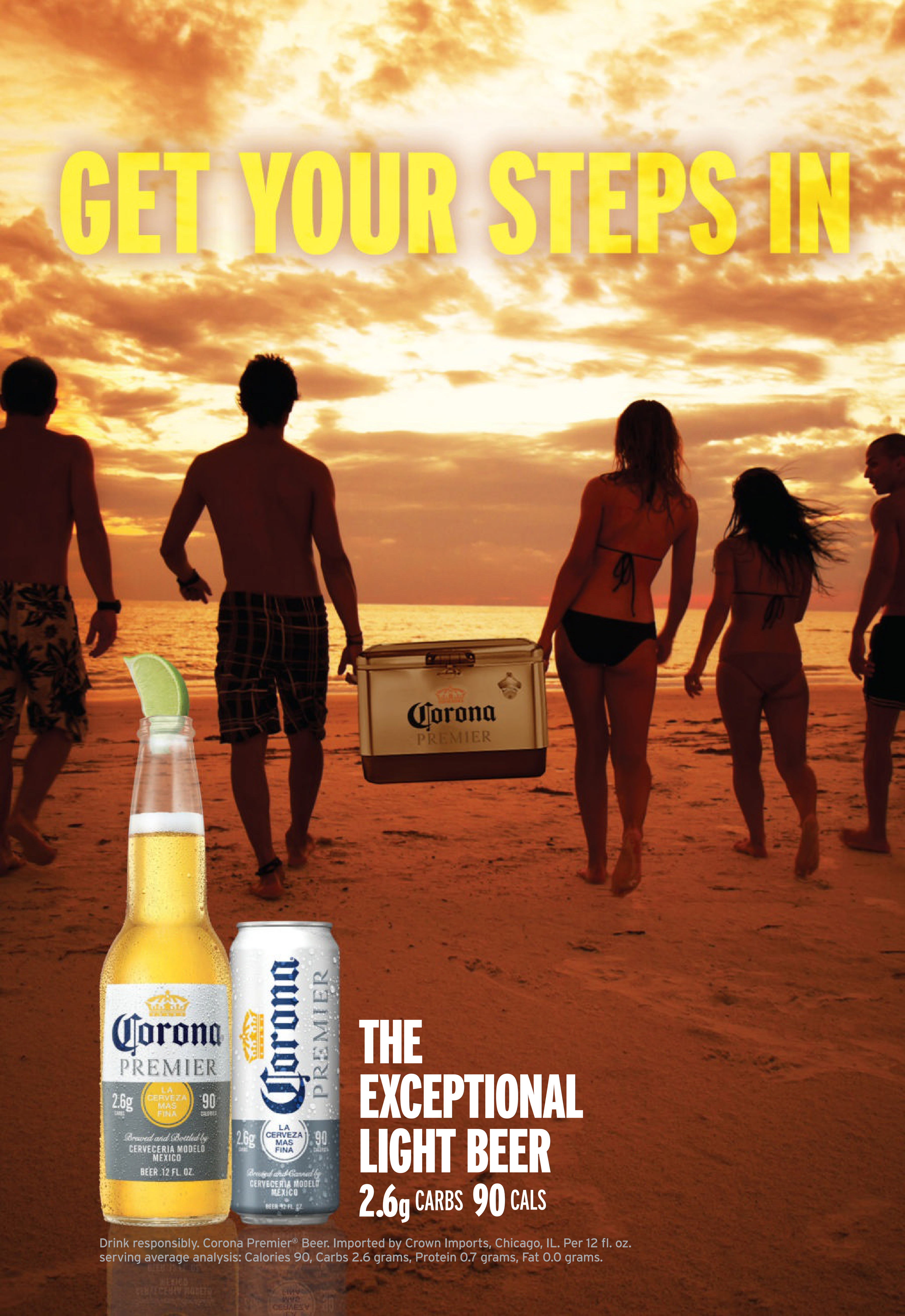
Whether it's an afternoon in the park or a patio party, avoid single-use items, which account for half of all plastic produced. If you do opt for disposable products, consider those made from palm leaves or fast-growing bamboo, and reuse them a few times when possible. A keyword search for "plant-based dishware" yields options for most needs and budgets.

4. AT THE BEACH

Algae-based plastic

Solutions to the tide of plastic waste on shorelines might lie within ocean organisms. Surfers, scientists, and designers are trying out algae instead of fossil fuels to make outdoor gear such as surfboards and flip-flops. No matter what you take to the beach, make sure it heads home with you.

PHOTO: REBECCA HALE, NGM STAFF



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San Francisco's Waverly Place, in the U.S.'s first Chinatown, is lined with temples, social clubs, and mom-and-pop shops.

CHANGES IN CHINATOWN

ROOTED IN BOTH RACISM AND MARKETING, THESE HISTORIC ENCLAVES GRAPPLE WITH UNCERTAIN FUTURES.

BY **RACHEL NG** PHOTOGRAPHS BY **ANDRIA LO**

BORN AND RAISED in Los Angeles's Chinatown, Glenn SooHoo has witnessed the growth, decline, and revitalization of his neighborhood for 50 years. In the past year and a half, this enclave—and others like it across North America—has been in crisis, buffeted by the twin traumas of xenophobia and a public health emergency.

"The virus is hampering business and the tourist industry," says SooHoo, owner of Phoenix Imports. "The virus didn't have anything to do with Chinatown, but [with] it being associated as an Asian thing by [then President Donald Trump], people just got that phobia about it."

As historic Chinatowns struggle during the pandemic, it's worth looking at why residents—and visitors—flocked to them in the first place.

Chinatowns have been in the United States for more than 170 years. The first one, in San Francisco, served as an unofficial port of entry for Chinese immigrants escaping economic and political chaos in the mid-1800s. Men sought their fortunes in the California gold rush, and when mining waned, they found work as farmhands, domestic helpers, and in the 1860s, workers for the transcontinental railroad.

They either were bachelors or had left wives and families behind in China, and they needed sleeping

PHOTO: Kostadin Luchansky
The National Geographic Okavango Wilderness Project
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quarters, clean clothes, and hot meals after long days of grueling labor. This led to a proliferation of housing, laundry services, and restaurants in burgeoning, Chinese-centric neighborhoods.

As the immigrants fanned out across the country seeking more work, Chinatowns mushroomed all over the U.S. At one time, there were more than 50.

But these Chinatowns were also born out of growing racial tension and discrimination in housing and employment. The Chinese Exclusion Act of 1882 and subsequent acts severely limited immigration for more than 60 years. Anti-Chinese sentiment resulted in street brawls, race riots, and even lynching and massacres. Many Chinatowns were destroyed by fire or natural disasters, or abandoned.

While the earliest Chinatowns were composed of modest wooden and brick buildings, the Asian motifs we see today—pagodas, tiled roofs, dragon imagery—came about as a way to promote tourism. When the original San Francisco Chinatown was destroyed by the 1906 earthquake and the devastating fire that followed, a group of wealthy Chinese merchants hired Scottish American architect T. Paterson Ross and engineer A.W. Burgren to design a new Chinatown. The plan incorporated religious iconography and architectural elements of the Song dynasty.

The new neighborhood was a fantasy vision of China, a country neither man had ever visited. The strategy worked: San Francisco's Chinatown was reborn as an "exotic" destination for Western tourists.

Some Chinatowns followed suit, adopting similar aesthetics, but others took a different tack. Instead of projecting a family-friendly atmosphere, Chinatowns in Chicago and New York City promoted a kind of "slum" tourism, where travelers were invited to revel in the sights, sounds, and smells of poor, ethnic neighborhoods. Visitors dined at chop suey restaurants, peeked into opium dens, and maybe witnessed a tong (Chinese secret society) gang fight.

Chinatowns' fortunes rose and fell over the decades. Civil unrest and urban decay, along with the search for more housing and job opportunities, prompted immigrants to move away from Chinatowns in Washington, D.C., and other cities, giving rise to new satellite communities in places like L.A.'s San Gabriel Valley and New York's Flushing, Queens.

But before the pandemic, downtown living in many cities had regained popularity, and commercial developers had started paying attention to once neglected Chinatown real estate. Luxury apartments and trendy restaurants took over rent-controlled buildings and mom-and-pop stores. These gentrified Chinatowns are shadows of their formerly vibrant selves, with only a handful of Chinese restaurants and, occasionally, an arched gateway left standing.

Many Chinese Americans are fighting back. The Chinese Culture Center of San Francisco hopes a mix of art and educational programming will help visitors and residents view the neighborhood as an "interactive site to deepen their understanding and sense of belonging," says curator Hoi Leung. She cautions that, without care and activism, Chinatowns will eventually disappear.

At L.A.'s Phoenix Imports, SooHoo is determined to ensure his shop's future. "We've been through everything, good and bad," he says. "I just want to keep this Chinatown alive for the next generation."

Rachel Ng is a Los Angeles–based writer. Photographer **Andria Lo** is based in Berkeley, California. Her book *Chinatown Pretty* celebrates Chinatowns throughout the U.S.

Chinatown tastes: In New York a vendor offers fresh jackfruit. In San Francisco, owner Kwan Sau Ling serves plant-based dishes at Lucky Creation Vegetarian Restaurant; operating since 1924, Eastern Bakery stocks boxed tea, cookies, and cakes.

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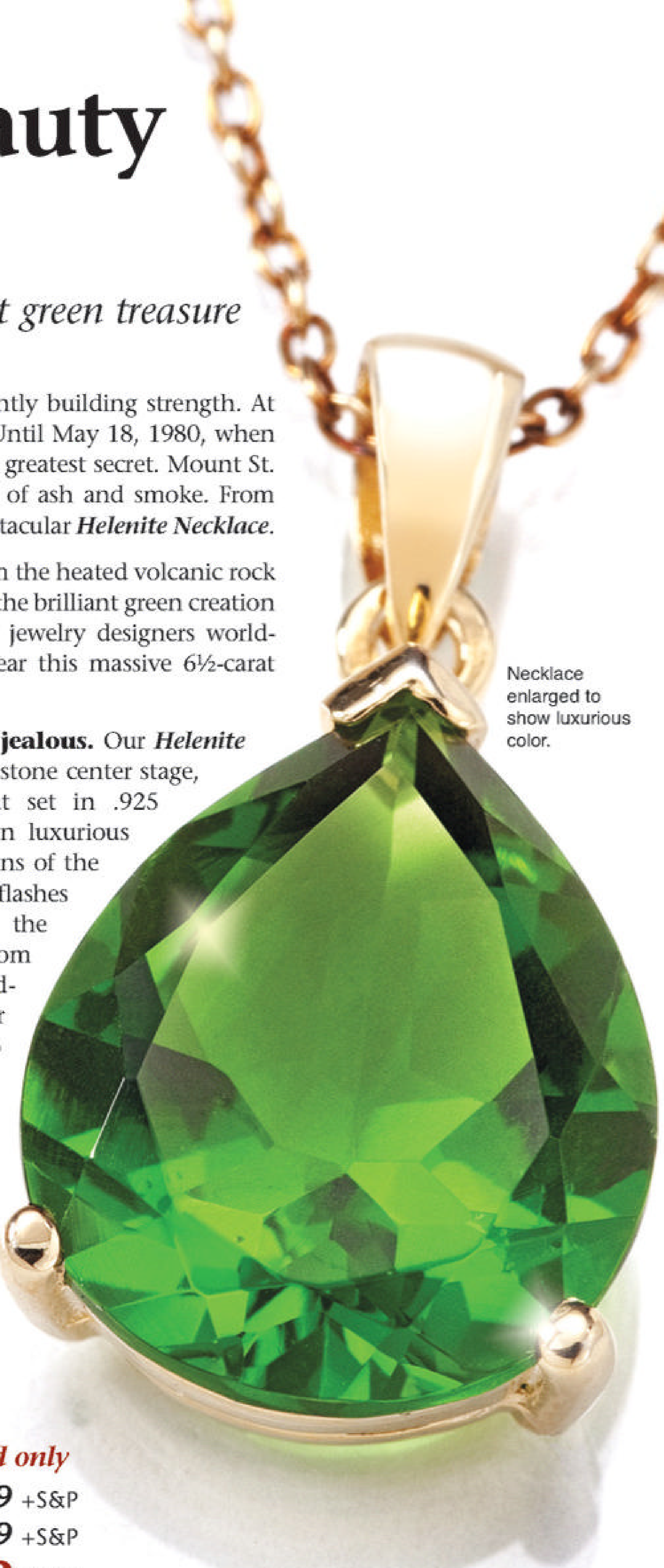

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STORY AND PHOTOGRAPHS BY
THOMAS PESCHAK

SOMETIMES THE BEST IMAGES are not the ones we plan for. Back in 2003 I was a marine biologist studying kelp forests for my Ph.D., but really I was rushing headlong into becoming a photographer.

I'd become convinced that I could make a bigger difference in conservation with images than with research. So instead of revising thesis chapters, I began spending most of my time making pictures. Increasingly those photographs were of great white sharks, a newfound obsession fueled by my friendship with biologist Michael Scholl of the White Shark Trust. Great whites were big, bold, charismatic—and in dire need of an image makeover.

One summer day Michael alerted me to a puzzlingly large number of sharks near South Africa's southern tip: nearly a dozen great whites concentrated along a one-mile stretch of beach, patrolling water less than six feet deep. They lurked right behind the breaking waves, just a stone's throw from the shore. It didn't take me long to make a plan and pack my gear to join him there.

To learn what the sharks were doing, we first thought to observe them from Michael's research boat. But that turned out to be difficult because the sharks reacted strongly—and in strangely opposite ways—to the noise of the boat. Some of them tried to bite the engines; others fled at the very sound of them.

We didn't have a budget for aerial reconnaissance, and small photographic drones had not yet been invented. Our research appeared to be stymied until I suggested a less disruptive and cheaper means of tracking them: a sea kayak.

Since it was my bright idea, I got to go first. After mounting a GPS on the kayak, I slipped into the seat and began paddling. Within a few minutes I was among the sharks. That first outing was nerve-racking: Imagine what separates you from one of the ocean's apex predators is less than one inch of plastic—and that plastic is bright yellow, a color some sharks find very attractive. Fortunately for me, the sharks never showed aggression toward my low-slung craft. I was able to follow them at close range and observe their natural behavior.

The photographer in me switched on, and I had a vision of an image I wanted to make: one of the sharks being trailed by a researcher in a kayak. Actually capturing the image, though, turned out to be complicated. There were usually plenty of great whites around the kayak—but the slightest gust of wind rippling the ocean surface would turn a shark's sleek outline into a cubist abstraction. I had to wait for calm conditions.

A few weeks later, conditions were right and I was ready. Harnessed to the flybridge of Michael's boat, I made photographs of researchers trailing sharks—pictures I thought were nice but unremarkable. I was down to the last few frames on a roll of film when a bold shark approached the rear of the kayak and rose in the water column. Just as its dorsal fin broke the surface, the scientist in the kayak looked back.

National Geographic's SharkFest celebrates the ocean's apex predators in July. Watch *Shark Beach With Chris Hemsworth* and other shark-infested programming on the network, and the feature documentary *Playing With Sharks* streaming on Disney+.

Instead of the scientist tracking the shark, the shark was tracking the scientist. I clicked the shutter.

The photograph resonated with people in a way I'd never expected. I received 100,000 visitors to my website in the first 24 hours. (In 2003, before the rise of social media, this was considered going viral.) Then things took an unexpected turn: More and more people suspected that I'd faked the picture. Conspiracy theories flourished online, with commenters analyzing everything from the angle of shadows to the ripples from the shark. I began bringing the original slide with me to media interviews as proof of its veracity. The image had put me on the map as a photographer and paid many bills, but I was fed up with having to defend it. When the phone stopped ringing, I was relieved.

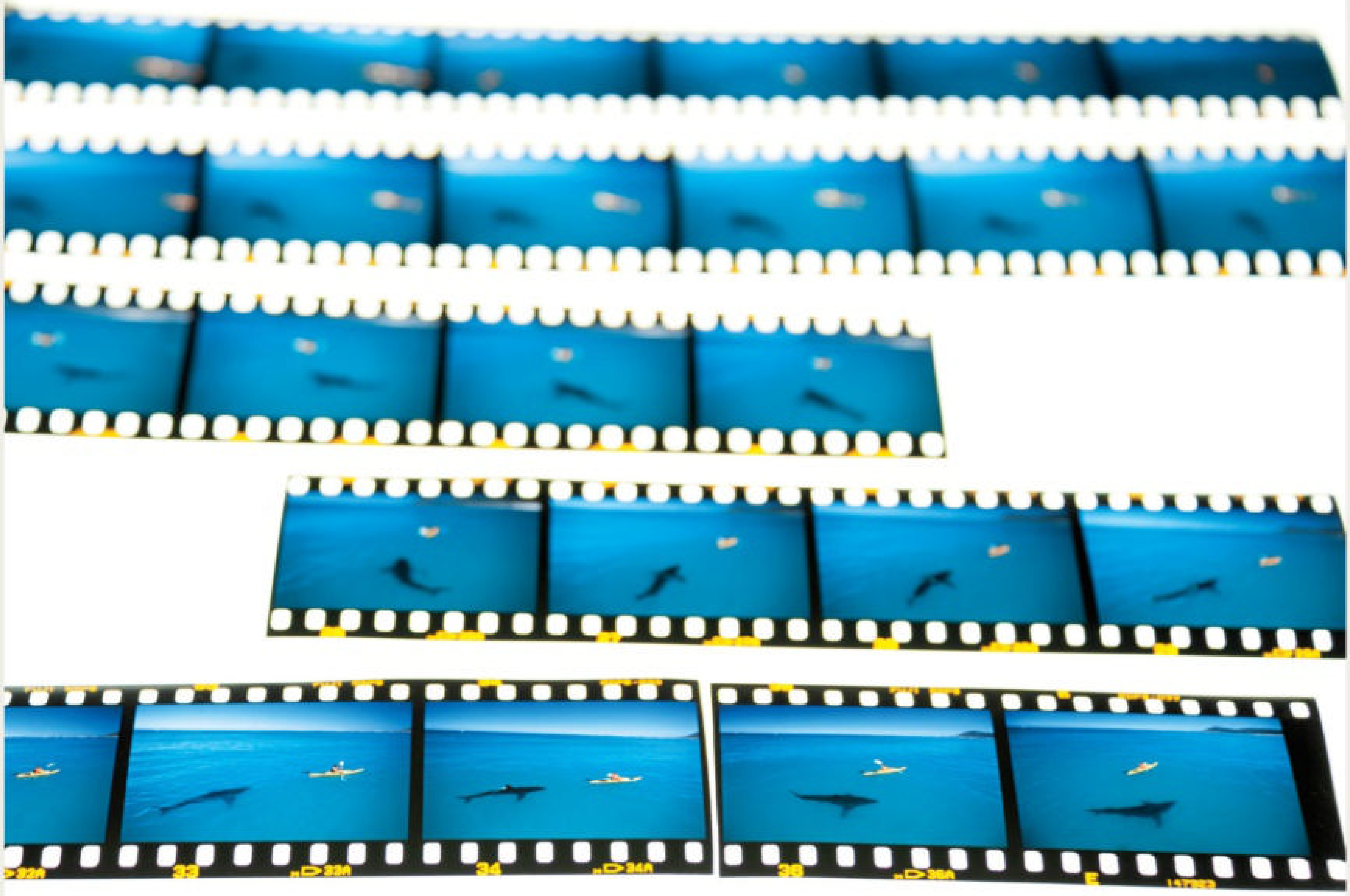
Several years later, the story of this photograph took a surreal turn. In 2011, as Hurricane Irene brought massive floods to Puerto Rico, Channel 7 News in Miami showed a photograph of a shark swimming up a flooded street. It was an astonishing scene, but the shark looked familiar.

It was my great white. Someone had photoshopped her into the storm's aftermath. In 2012 she appeared again, this time swimming up a submerged highway in New Jersey after Hurricane Sandy. In 2017 she meandered along Houston's flooded streets after Harvey. When an internet prankster claimed that the shark tank at Kuwait's Scientific Center had collapsed, it was my shark that was digitally added, swimming next to an escalator which itself was from an image of flooding at Toronto's Union Station. Most recently, after Hurricane Laura devastated the coast of Louisiana, I received a text reading: "Guess who's back?" I clicked on the link, and there she was.

Few people are indifferent to sharks, which is why these faked images are so compelling. These fish have a way of commanding our attention. As a photographer and storyteller, I take advantage of that. With a powerful image and story, I can transform sharks from dark, menacing creatures into vulnerable animals worthy of respect and protection.

Sharks are storytellers too. They communicate some of the most pressing conservation issues facing our oceans, such as overfishing and climate change. But we have to listen. Though at first that kayak photograph appears foreboding, its true story is quite the opposite—a tale of wonder, curiosity, coexistence. From one picture have come countless chances to tell people more about sharks—conversations that often begin in fear and ignorance but end in fascination. □

National Geographic Explorer **Thomas Peschak** is a photographer and marine biologist. His book *Wild Seas* will be published by National Geographic in October 2021.



A developed roll of slide film shows the moments leading up to the shark picture on the previous page.

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FEATURES

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'CONDITIONS IN LA RINCONADA HARM WORKERS' HEALTH AND POISON THE ANDEAN LANDSCAPE, BUT THAT HASN'T STOPPED BUYERS AND REFINERS IN THE U.S., SWITZERLAND, AND OTHER COUNTRIES FROM PURCHASING LA RINCONADA'S GOLD.'

PHOTO: CÉDRIC GERBEHAYE

TOO HOT TO

Rising heat in the 21st century is likely to push millions of people and entire regions out of their comfort zones.

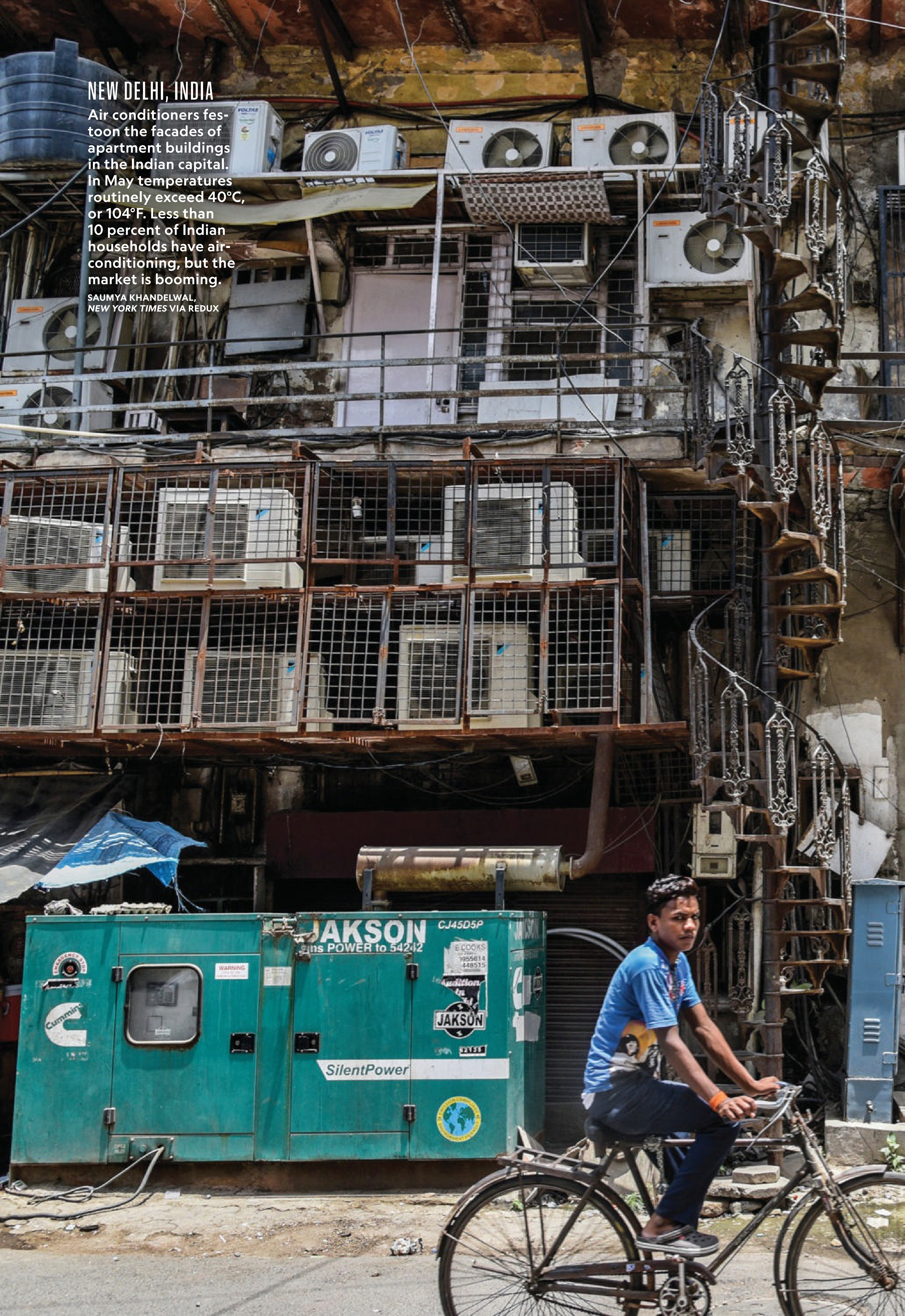
BY **ELIZABETH ROYTE**

DASHT-E LUT, IRAN

A morning traveler surveys what might be Earth's hottest place: the Lut Desert. In 2014 French researchers measured an unofficial 142°F in the shade here—a potential world record, if repeated with standard instruments. As Earth warms, more of it may become like the Lut—inhospitable to humans.

MATTHIEU PALEY

LIVE



NEW DELHI, INDIA

Air conditioners festoon the facades of apartment buildings in the Indian capital. In May temperatures routinely exceed 40°C, or 104°F. Less than 10 percent of Indian households have air-conditioning, but the market is booming.

SAUMYA KHANDELWAL, *NEW YORK TIMES* VIA REDUX

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PARIS, FRANCE

The Trocadéro fountain offers relief during a record-smashing 2019 heat wave. A disastrous predecessor in 2003 had triggered reforms, such as a requirement for cooling in nursing homes. They paid off: The 2019 death toll in France was 90 percent lower.

SAMUEL BOIVIN, NURPHOTO VIA GETTY IMAGES

T

THE HUMAN BODY HAS EVOLVED to shed heat in two main ways: Blood vessels swell, carrying heat to the skin so it can radiate away, and sweat erupts onto the skin, cooling it by evaporation. When those mechanisms fail, we die. It sounds straightforward; it's actually a complex, cascading collapse.

As a heatstroke victim's internal temperature rises, the heart and lungs work ever harder to keep dilated vessels full. A point comes when the heart cannot keep up. Blood pressure drops, inducing dizziness, stumbling, and the slurring of speech. Salt levels decline and muscles cramp. Confused, even delirious, many victims don't realize they need immediate help.

With blood rushing to overheated skin, organs receive less flow, triggering a range of reactions that break down cells. Some victims succumb with an internal temperature of just 104 degrees Fahrenheit (40 degrees Celsius); others can withstand 107 degrees for several hours. The prognosis is usually worse for the very young and for the elderly. Even healthy older people are at a distinct disadvantage: Sweat glands shrink with age, and many common medications dull the senses. Victims often don't feel thirsty enough to drink. Sweating stops being an option, because the body has no moisture left to spare. Instead, sometimes it shivers.

A heart attack may fell the infirm at this point, but the more fit may persist to suffer tunnel vision, hallucinations, and perhaps the stripping of clothes that, with nerve endings aflame, feel like sandpaper. Fainting is now a blessing, as blood vessels begin to lose their integrity. Muscle tissues, including those of the heart, may go next. Once the digestive tract starts to leak, toxins enter the bloodstream. The circulatory system responds with a massive, last-ditch clotting effort that further endangers vital organs—kidneys, bladder, heart. Death is near.

IN THE SUMMER OF 2003 an area of high atmospheric pressure camped out above western and central Europe.

PARIS, FRANCE

After another record heat wave in 2019, the public transit agency experimented with misters on the Parc de St.-Cloud tram platform. As the tiny droplets of filtered water evaporate, they cool the air enough to refresh passengers.

WILLIAM DANIELS

Superheated over the Mediterranean, the giant swirling air mass rebuffed incursions of cooler Atlantic air for several weeks. In France, temperatures rose steadily, topping out for eight days at an astonishing 104°F (40°C). As the heat built up, people began to die.

Many physicians and first responders were away on their annual vacations, and hospitals soon were overwhelmed. Morgues filled up, and refrigerated trucks and food-market freezers took up the slack. Visiting caregivers found clients slumped on their floors or dead in armchairs. (At the time only a few percent of French households had air-conditioning.) Police were called to break doors open, "only to find corpses behind them," recalls Patrick Pelloux, president of the French association of emergency room doctors. "It was absolutely appalling." Many of the bodies were not discovered for several weeks.

France eventually attributed more than 15,000 deaths to the heat wave. Italy fared even worse, with nearly 20,000. Across the continent, more than 70,000 people—most of them poor, isolated, and elderly—lost their lives. Europe's hottest summer in 500 years, scientists later determined, was clearly linked to climate change. In Paris it had raised the risk of heat-related mortality that year by about 70 percent.

Among the many climatic threats that scientists associate with global warming—stronger and more destructive hurricanes, drought, rising sea levels, longer fire seasons—an uptick in heat waves is the most intuitive and immediate. As greenhouse gases released by human activities continue to increase in the atmosphere, heat waves will become longer and individual days will become hotter. Globally, the past six years have been the warmest ever recorded. In the southwestern United States, days with triple-digit temperatures are arriving weeks earlier than they did a century ago and lingering three weeks longer. And in Europe, the dreadful summer of 2003 has proved to be no mere statistical blip: Major heat waves have hit the continent five times since then, and 2019 brought all-time temperature records in six western European countries, including 114.8°F in France.

The ultimate solution to global warming, of course, is to drastically reduce our greenhouse gas emissions. If we fail utterly to do that, by 2100 the heat-related death toll could rise above 100,000 a year in the U.S. Elsewhere the threat is far greater: In India, for example, the death toll could reach 1.5 million, according to recent research. And even if we do rein in emissions, the planet will continue to warm for decades. A juggernaut is in motion, and it will fundamentally change how most of the planet lives.

Extreme heat has pernicious effects even when it isn't lethal. Researchers link higher temperatures with a greater incidence of premature, underweight, and stillborn babies, and heat exhaustion affects mood, behavior, and mental health. Hotter weather makes people more violent, across income levels. It lowers children's test scores and shrinks productivity. The International Labour Organization predicts that high heat levels will, by 2030, cut total working hours by 2.2 percent, equivalent to losing 80 million full-time jobs, mostly in low- to middle-income countries. Even in affluent ones, low-wage outdoor workers—in construction or agriculture, for example—will be hit hard. By 2050, high heat and humidity in the American Southeast likely will render the entire growing season "unsafe for agricultural work with present-day work practices," researchers at the University of Washington have reported.

Humans, along with their crops and their livestock, evolved over the past 10,000 years in a rather narrow climate niche, centered on an annual average temperature of about 55°F (nearly 12.8°C). Our bodies readily adapt to higher temperatures, but there are limits to how much heat and humidity we can tolerate.

Even the fittest, heat-acclimated person will die after a few hours' exposure to a 95° "wet bulb" reading, a combined measure of temperature and humidity that takes into consideration the chilling effect of evaporation. At this point, the air is so hot and humid it no longer can absorb human sweat. Taking a long walk in these conditions, to say nothing of harvesting tomatoes or filling a highway pothole, could be fatal. Climate models predict that wet-bulb temperatures in South Asia and parts of the Middle East will, in roughly 50 years, regularly exceed that critical benchmark.

IN 50 YEARS, A THIRD OF THE WORLD'S PEOPLE COULD LIVE IN PLACES THAT FEEL LIKE THE SAHARA—WHERE **THE AVERAGE SUMMER HIGH TOPS 104°F.**

By then, according to a startling 2020 study in *Proceedings of the National Academy of Sciences,* a third of the world's population could be living in places—in Africa, Asia, South America, and Australia—that feel like today's Sahara, where the average high temperature in summer now tops 104°F. Billions of people will face a stark choice: Migrate to cooler climates, or stay and adapt. Retreating inside air-conditioned spaces is one obvious work-around—but air-conditioning itself, in its current form, contributes to warming the planet, and it's unaffordable to many of the people who need it most. The problem of extreme heat is mortally entangled with larger social problems, including access to housing, to water, and to health care. You might say it's a problem from hell.

PHOENIX, ARIZONA, is the hottest city in the U.S., with more than 110 triple-digit days a year. Unsurprisingly, it also regularly records the most heat-related deaths. In 2020, Maricopa County logged an all-time-record 207, according to its medical examiner's office, which occupies a two-story, desert-tone building in downtown Phoenix and is required by law to investigate all nonnatural deaths, which include those related to temperature.

When a potentially heat-related death is reported, says Melanie Rouse, the office's chief investigator, her staff first interviews anyone with recent knowledge of the decedent. Was she or he sweating profusely or not at all, complaining of headache or nausea? Doing yard work? Using alcohol or drugs, which interfere with thermoregulation? "What we're trying to find out," Rouse says, "is what led to this turn in their life. We're trying to see if there are other compelling causes of death."

At the death scene, investigators measure the temperature of the body and the room. (The highest indoor temperature they've recorded was 145°F in 2017.) They extract vitreous fluid from the victim's eyeball for chemical analysis. Cells break down quickly in high heat, explains Rouse, "but the globe of the eyeball is a protected space." Chemists and physicians will analyze this fluid to determine if the decedent was dehydrated, had high blood sugar, or had decreased kidney function—all of which increase susceptibility to heat.

Slightly more than half of Maricopa County's heat-related deaths occur outdoors, mostly among the homeless. Many of the indoor deaths occur in mobile homes, whose poor insulation makes them hard to cool. Even in the richest of countries, inadequate housing contributes massively to heat exposure. In poorer countries, matters are far worse.

In India, when the temperature surpasses 105°, government agencies advise people to stay inside and drink cool water. But the advice is not helpful to the tens of millions whose homes are hotter inside than out, who lack electricity to operate fans or misters—only 8 percent of Indian households have air-conditioning—or who, like Noor Jehan, don't have homes at all.

Jehan, 36, has lived outdoors, in a South Delhi park, all her life. Every morning she stacks her meager belongings—a sack of bedding, a few pots and bowls—near a concrete perimeter wall, then trudges to her job at a construction site. She works even when the thermometer reaches 118°. Like millions of other daily wage laborers, she can't feed her three children if she skips work. "When I come back home," she says, "there's no water to even take a bath to clean the grime and dust and cool down." Her drinking water source is more than a mile away.

Jehan's husband pulls a rickshaw, but, undernourished and dehydrated, he frequently faints in the heat. Her sister Afsana and her three children cope by placing mats on the sidewalks, to rest or even sleep. "The passing cars create a bit of breeze," Afsana says. But the sidewalks often don't cool off until about 2 a.m.

In Phoenix, David Hondula of Arizona State University studies the social and health impacts of unrelenting urban heat. Usually he can be found analyzing data in an air-conditioned office, but lately he's been pounding the city's blistering pavement to map the best places to plant tens of thousands of shade trees—an increasingly common urban response, around the world, to rising temperatures. "Less heat exposure reduces risk," Hondula says, "but I don't think we should rely on tree planting to prevent people from dying of heat."

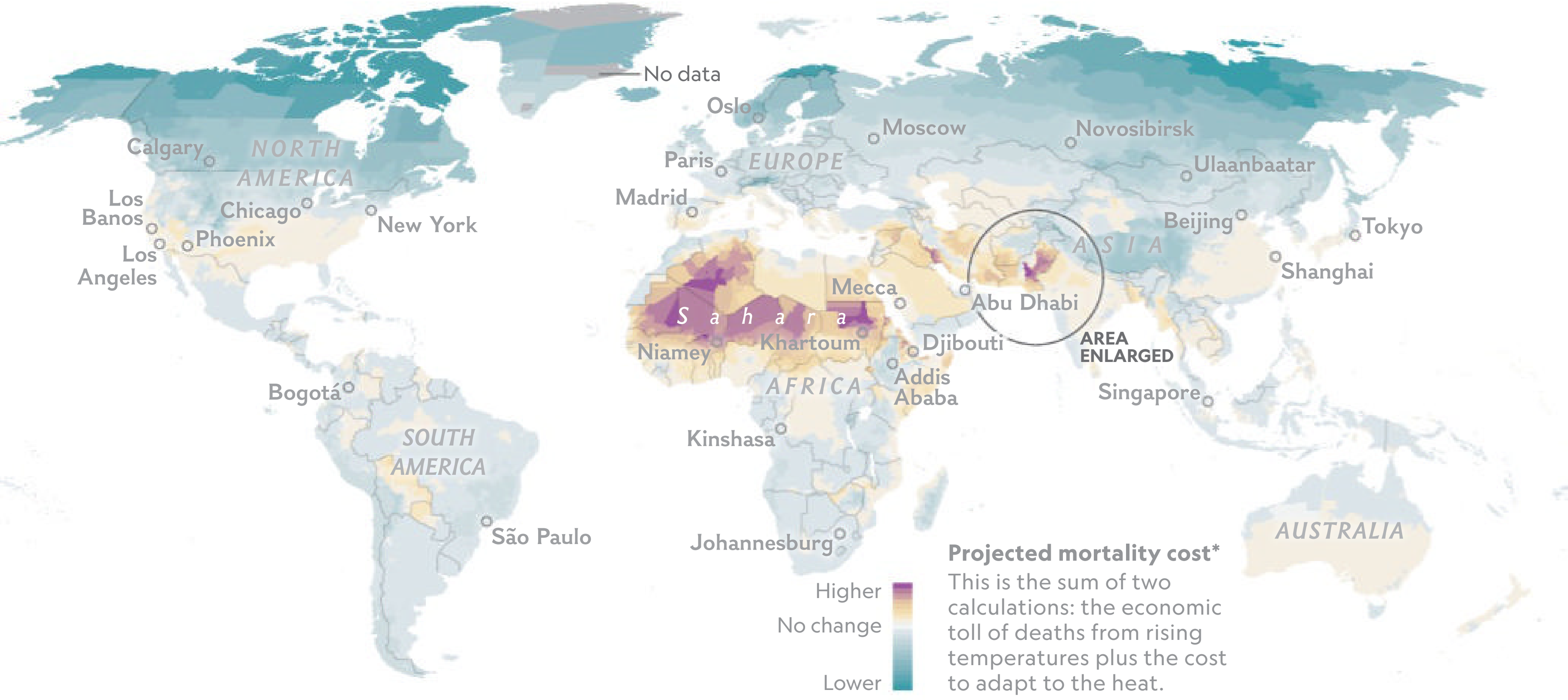
Asked what a more appropriate response might be, he does not hesitate.

"Increasing access to air-conditioning."

HISTORICALLY, RESIDENTIAL air-conditioning has been considered a luxury, with especially frigid indoor temperatures signifying power and prestige. But in many places it's becoming a public health necessity, essential for preventing heat-related deaths. The good news, according to the Climate Impact Lab, a consortium of climate researchers, is that by 2099 economic development is expected to increase both air conditioner use and access to health care, saving millions of lives a year. The International Energy Agency projects that the number of AC room units will soar to 5.6 billion by mid-century, from 1.6 billion today.

The bad news is that current air-conditioning technology exacts a steep price on the planet. In most systems a liquid refrigerant is pumped through an evaporation coil within the indoor part of an AC unit; as the liquid changes to gas inside the coil, it pulls heat and moisture from the air. Outside the building a compressor, a condenser, and a fan convert the gas back to a liquid, releasing the heat and the condensed water.

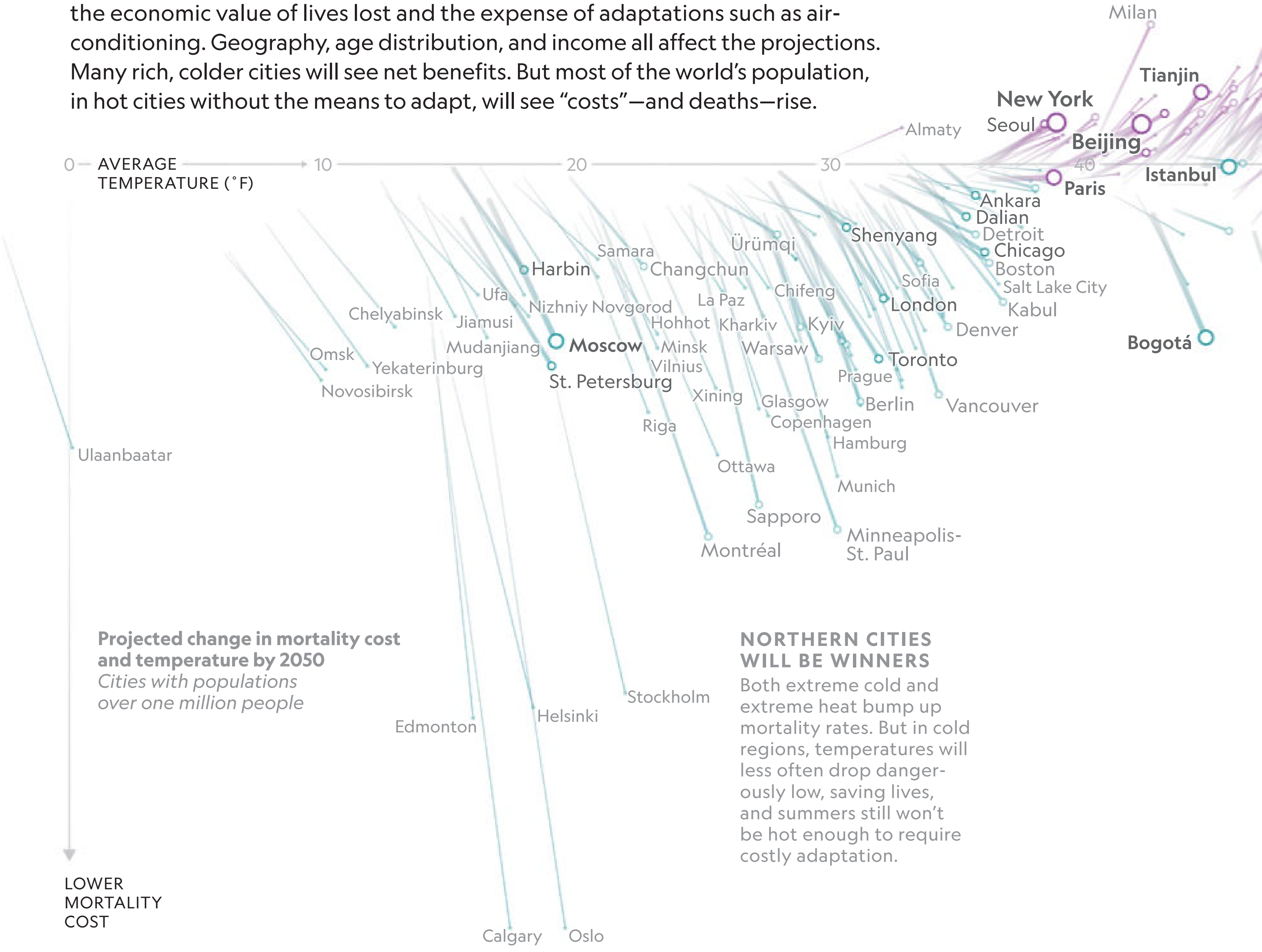
There are three problems with this ingenious, century-old approach. First, the hydrofluorocarbons that typically are used as refrigerants are themselves greenhouse gases, and when they leak to the environment—should they be



Projected mortality cost*
This is the sum of two calculations: the economic toll of deaths from rising temperatures plus the cost to adapt to the heat.

THE HIGH PRICE OF HEAT

Rising heat will kill more people by 2050, but people will also adapt. Researchers at the Climate Impact Lab projected future "mortality costs," reflecting both the economic value of lives lost and the expense of adaptations such as air-conditioning. Geography, age distribution, and income all affect the projections. Many rich, colder cities will see net benefits. But most of the world's population, in hot cities without the means to adapt, will see "costs"—and deaths—rise.



Projected change in mortality cost and temperature by 2050
Cities with populations over one million people

NORTHERN CITIES WILL BE WINNERS
Both extreme cold and extreme heat bump up mortality rates. But in cold regions, temperatures will less often drop dangerously low, saving lives, and summers still won't be hot enough to require costly adaptation.

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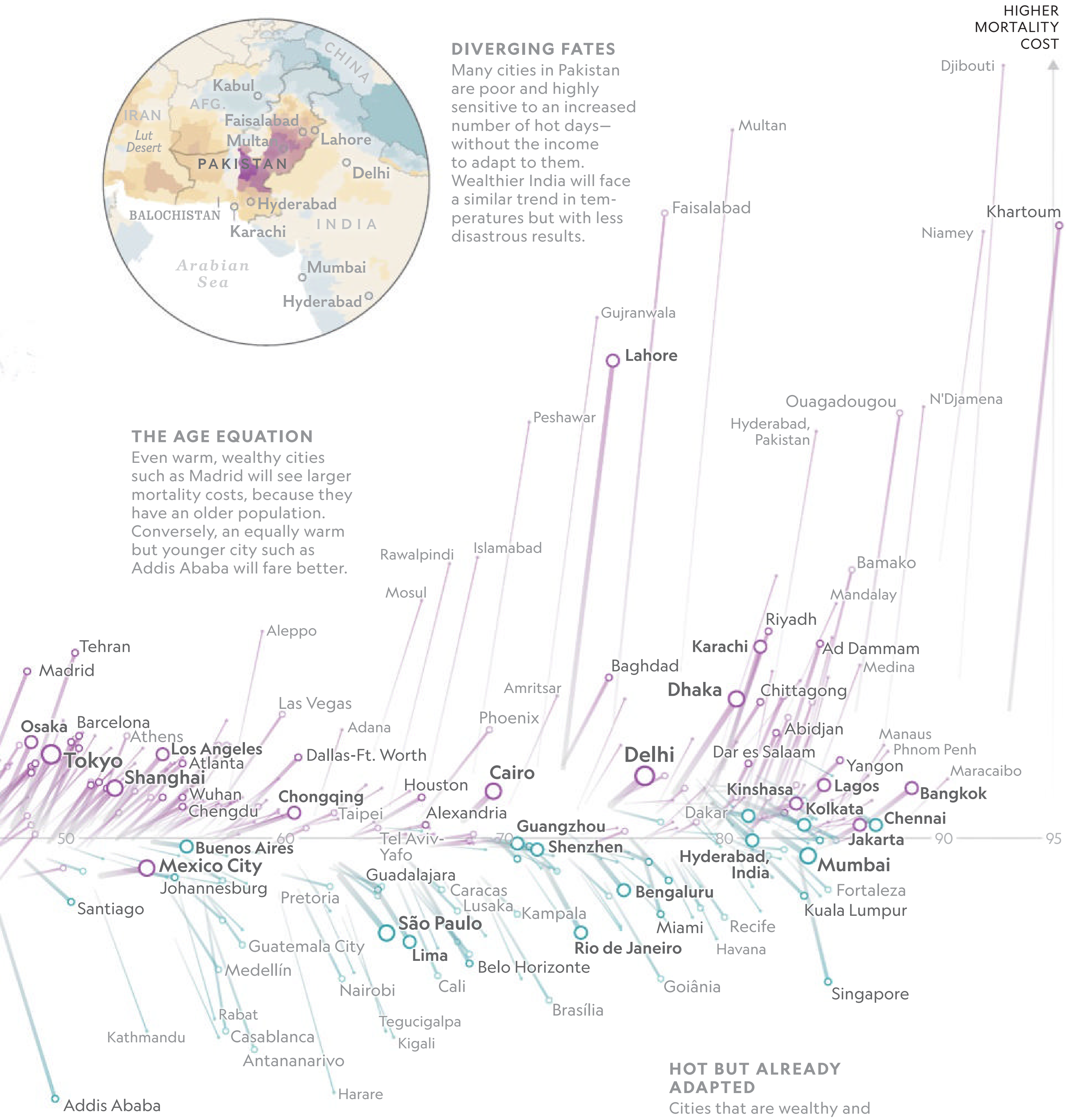
*The Intergovernmental Panel on Climate Change identifies future climate scenarios, called representative concentration pathways (RCPs), ranging from worst-case scenario, RCP 8.5, to best, RCP 2.6. Data here use RCP 4.5 for 2040–2059 projections.



DIVERGING FATES

Many cities in Pakistan are poor and highly sensitive to an increased number of hot days—without the income to adapt to them. Wealthier India will face a similar trend in temperatures but with less disastrous results.

THE AGE EQUATION

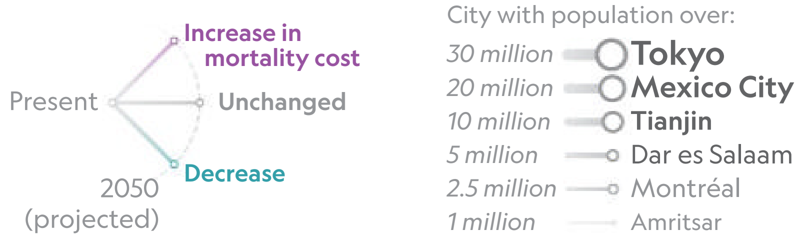
Even warm, wealthy cities such as Madrid will see larger mortality costs, because they have an older population. Conversely, an equally warm but younger city such as Addis Ababa will fare better.

HOT BUT ALREADY ADAPTED

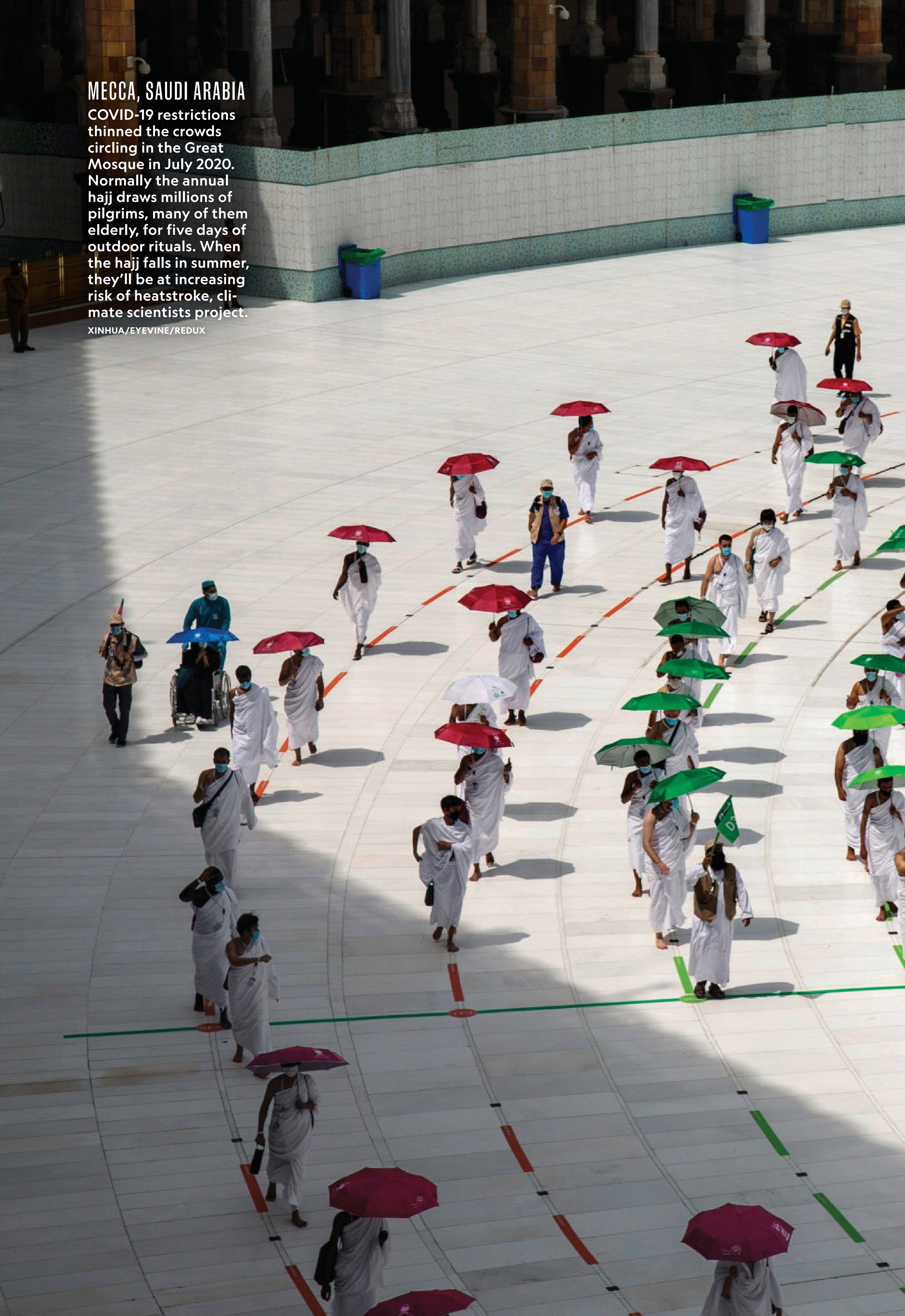
Cities that are wealthy and very hot, such as Singapore, will see a decline in mortality cost. Already well adapted to a hot climate, with widespread air-conditioning, they're projected to grow even richer by 2050.

How to read this chart

The beginning of a city's line shows its average temperature and mortality cost in 2019; the endpoint of its line shows its projected temperature and mortality cost in 2050.



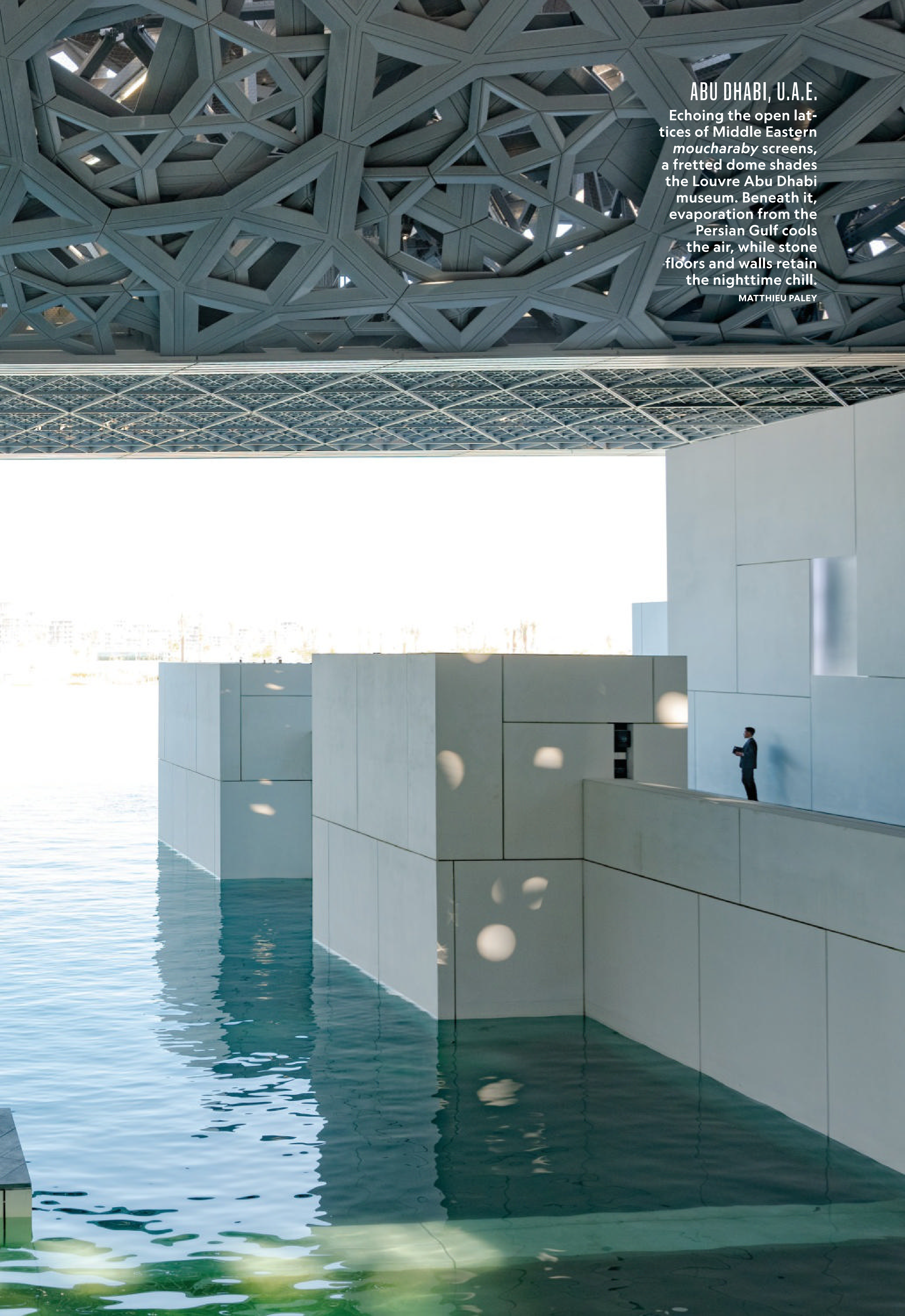
JASON TREAT, CHRISTINE FELLENZ, AND EVE CONANT, NGM STAFF
SOURCE: CLIMATE IMPACT LAB



MECCA, SAUDI ARABIA

COVID-19 restrictions thinned the crowds circling in the Great Mosque in July 2020. Normally the annual hajj draws millions of pilgrims, many of them elderly, for five days of outdoor rituals. When the hajj falls in summer, they'll be at increasing risk of heatstroke, climate scientists project.

XINHUA/EYEVINE/REDUX



ABU DHABI, U.A.E.

Echoing the open lattices of Middle Eastern *moucharaby* screens, a fretted dome shades the Louvre Abu Dhabi museum. Beneath it, evaporation from the Persian Gulf cools the air, while stone floors and walls retain the nighttime chill.

MATTHIEU PALEY

NEW YORK CITY, U.S.

At Columbia University, a panel coated with a novel polymer film radiates heat through the atmosphere to outer space—and thus, as this infrared image shows, is dramatically cooler than its surroundings. Deployed on rooftops, such panels could reduce the need for air-conditioning. Research into "radiative cooling" is growing.

JYOTIRMOY MANDAL

improperly disposed of—they have a global warming potential thousands of times greater, molecule for molecule, than carbon dioxide. Second, conventional air conditioners don't make heat vanish; they just dump it outside. In Phoenix, according to one study, ACs raise the outdoor temperature at night by as much as two degrees Fahrenheit, forcing all units to work even harder.

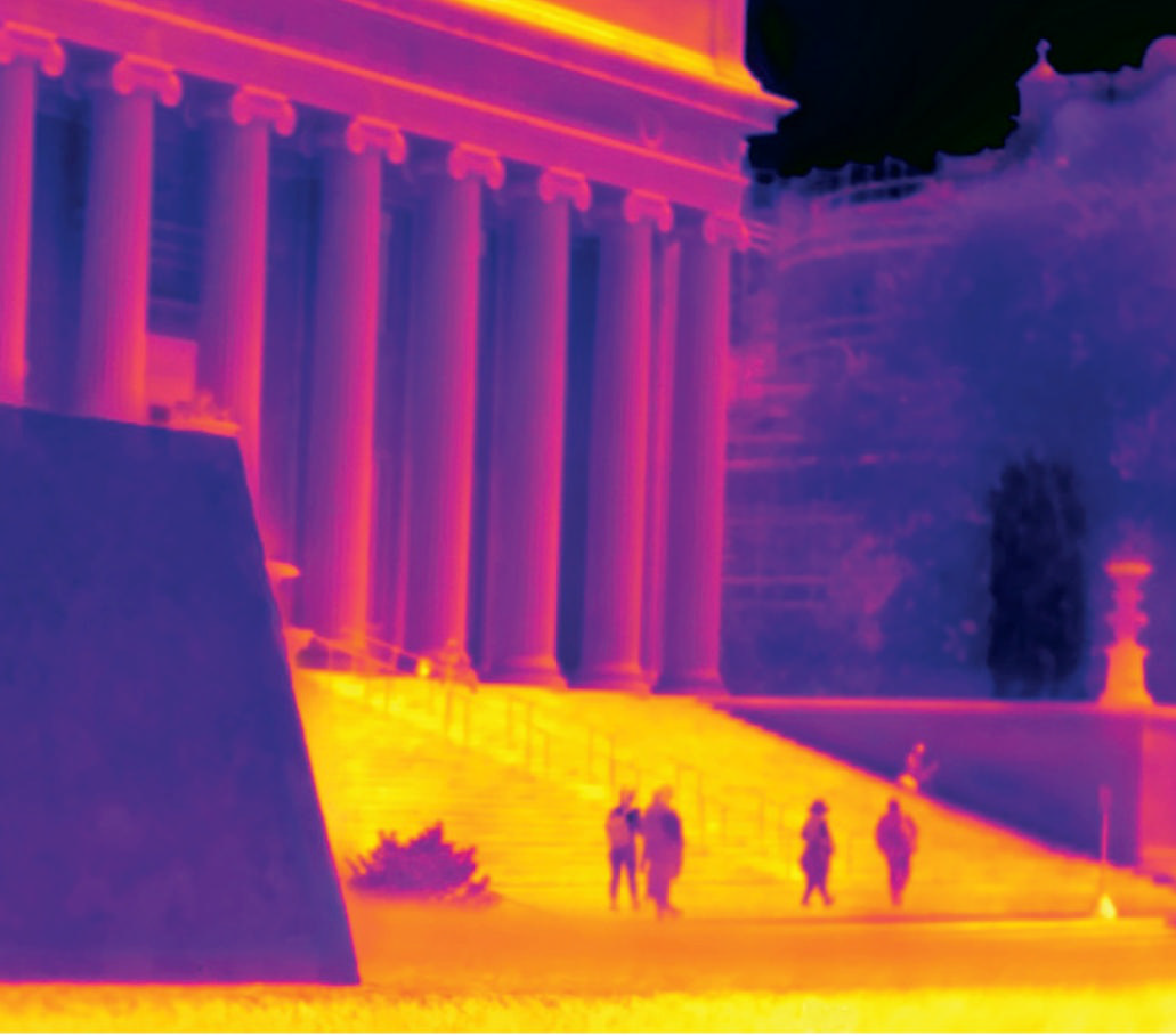
And third, air conditioners suck huge amounts of electricity—about 8.5 percent of total global consumption. Most of that energy is still produced by burning fossil fuels. In 2016 air-conditioning accounted for 1.25 billion tons of carbon dioxide emissions; by 2050, that number is expected to nearly double.

Clearly, new ideas are needed. To stimulate them, the Rocky Mountain Institute, a Colorado-based think tank, recently helped run an international competition. It challenged engineers to produce a room air conditioner that has one-fifth the climate impact of today's standard products, uses at most one-fourth the energy, and is no more than twice as expensive as a current baseline model.

Some entries dispensed with liquid refrigerants and vapor compression in favor of promising new technologies that weren't quite ready for prime time. One used solid-state refrigeration, in which pressure is cyclically applied to crystalline materials that switch readily from hot to cold; it's likely to prove more suitable for spot applications, such as quickly cooling a soda can, than for chilling an entire room. Another entrant proposed rooftop panels coated with nanomaterials that reject solar heat, radiating it back out to space at an infrared wavelength that passes right through the atmosphere. That could, in principle, reduce a building's heat gain by several degrees Fahrenheit, "but it isn't a solution on its own," says Rocky Mountain Institute senior fellow Iain Campbell. "It doesn't work in humid conditions, and the panels have to face the sky." Not so helpful, that is, for residents on the third floor of a 10-story building.

The final four contestants, which battled it out in 2020 during a post-monsoon "chill off" in a Bahadurgarh, India, apartment building, all relied on conventional vapor compression. But they were seriously souped up, using new refrigerants with low or no greenhouse-warming potential and hyperefficient evaporator and condenser systems. The co-champions, designed by Team Daikin and Team Gree, cool their condensers with water instead of air to reduce their energy demand, and one sports solar panels to supply some of its electricity. They are expected to be on store shelves by 2025, at about twice the price of the baseline model. But their operating costs are so low, Campbell says, that the payback period will be just three years.

AT PRINCETON UNIVERSITY in New Jersey, Forrest Meggers, an architect and engineer, is developing another type of system that might prove enormously helpful in hot and humid environments. It didn't meet the criteria for the Rocky Mountain Institute competition, though, because it doesn't cool a room's air: It cools only people—by absorbing the heat that radiates from their skin



with wall-mounted panels of water-filled tubes.

A prototype of the invention, called Cold Tube, hangs from a hook in Meggers's lab. It resembles a woven mat of blue plastic straws. On an 85° day like today, Meggers explains during my visit, filling those skinny tubes with 60° water would give lab occupants a feeling of 75°, even with the lab's sliding doors wide open because of the COVID-19 pandemic. Unfortunately, the tubes aren't filled on this muggy afternoon. Meggers is dressed head to toe in wicking clothing.

Architects have employed radiative cooling panels before, on ceilings and on walls, but almost always with dehumidifiers, to keep water from condensing on the panels and raining down on computers and heads. By shrouding his panels with a simple polyethylene membrane, which keeps humid air away from the tubes but not radiated heat, Meggers says, he has solved that problem.

In superhumid Singapore, where the Cold Tube was first deployed, the system produced a comfortable—but hardly cold—environment using less than half the energy of a conventional air conditioner and generating half the waste heat. The energy savings aren't quite as spectacular in arid environments, where ACs don't work so hard to dehumidify air. But the membrane-insulated radiative panels, Meggers says, are still more efficient than conventional systems.

Because the panels cool human bodies, not huge volumes of air, they could work well even in outdoor settings, such as bus shelters or cafés. The biggest challenge to wider adoption of the

CALIFORNIA, U.S.

In Los Banos, in the San Joaquin Valley, tomato pickers start at 5 a.m. to avoid some of the day's heat. State law requires growers to provide water, shade, and rest breaks, but pickers paid by the bucket may disregard such safeguards. Outdoor work will become increasingly dangerous in parts of the U.S.

KARLA GACHET

TAR
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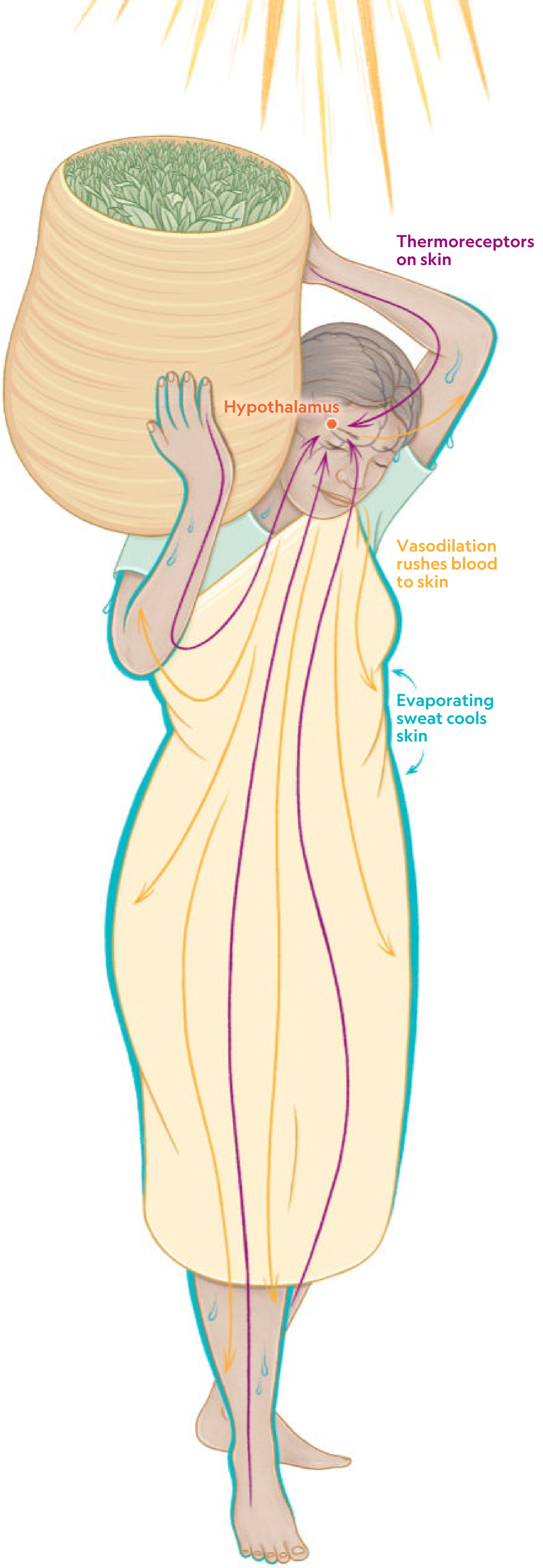
21

HOW THE BODY HANDLES HEAT

Maintaining a constant internal temperature of about 98.6°F is a balancing act. Muscles and organs generate heat that is shed through the skin. But the body also absorbs heat from the environment. A warming climate is exposing almost a third of the world's population to potentially deadly heat.


Thermoreceptors on skin
Hypothalamus
Vasodilation rushes blood to skin
Evaporating sweat cools skin

A system for cooling off

The body transfers heat to anything it touches, including clothes and the surrounding air. Heat radiating from the skin and sweat evaporating from it provide most of the body's cooling.

1 **HEAT STRESS IS DETECTED**
Receptors in the skin and other parts of the body sense that a person is starting to overheat. Climate, activity level, and clothing can all affect internal temperature.

2 **THE BODY'S THERMOSTAT TAKES NOTE**
The brain's hypothalamus signals eccrine glands in the skin to release sweat—up to three pounds an hour. Only about 5 percent of the 2.5 million glands are active at any given time.

3 **BLOOD IS RUSHED TO THE SKIN**
Blood vessels dilate, funneling more blood into capillaries in the skin. This vasodilation carries heat from the body's core to its surface, where it can be radiated away.

4 **BLOOD AND SWEAT COOL THE BODY**
Blood and sweat dissipate the vast majority of body heat through the skin; breath carries away most of the rest. Sweat cools when it evaporates, which can be nearly impossible in high humidity.

When things go wrong

The longer blood and fluids are diverted to cool the skin, the harder it is on our internal organs. In extreme heat, stress can progress to exhaustion and then stroke—and ultimately to death.

HEAT EXHAUSTION

Nausea, fatigue, cramps, rash, and dizziness—often caused by a combination of high temperatures, physical exertion, and high humidity—are signals the body sends to the brain to reduce activity and cool down. These symptoms can progress to more deadly heatstroke.

HEATSTROKE

Headache, confusion, vomiting, and loss of consciousness can occur when the body hits 104°F. Heatstroke requires emergency care. It can quickly damage the brain, heart, kidneys, and muscles and end in coma and death.

JASON TREAT AND EVE CONANT, NGM STAFF;
KELSEY NOWAKOWSKI
ART: GABY D'ALESSANDRO
SOURCES: OLLIE JAY, UNIVERSITY OF SYDNEY;
JASON LEE, NATIONAL UNIVERSITY OF SINGAPORE

technology, Meggers suspects, is attitudinal. "Engineers are accustomed to thinking about summertime comfort and cooling in terms of air-conditioning," he says. Adapting to a hotter world is going to require a paradigm shift, and not just among engineers.

NEW YORK CITY, WHERE I LIVE, ranks its neighborhoods' vulnerability to heat based on risk factors such as poverty, access to air-conditioning, and availability of green space. The upper Manhattan neighborhood of East Harlem scores five—the worst—on this index. Its poverty rate of 31 percent is nearly twice the city average, and it has among the lowest rates of air conditioner ownership—88 percent—in the city. But race matters too.

On a sizzling summer day I meet Sonal Jessel, the policy director for the nonprofit WE ACT for Environmental Justice, to walk through East Harlem. As we walk, Jessel draws my attention to a tenement building, where towels and rags fill the gaps between air conditioners and window frames.

"Their bill must be through the roof," she says. East Harlem is 27 percent Black, and Black households pay, on average, hundreds of dollars more per year for energy than do white households of comparable income, Jessel says, citing a study from the University of California, Berkeley.

Black Americans use more energy, that study suggested, in part because a legacy of racial discrimination has left them with less accumulated wealth and thus less ability to invest in insulation or the most efficient air conditioners. Their buildings are older and leakier, Jessel says, and their living conditions may be more crowded. "If you're trying to work or study in the air-conditioned living room and there's three noisy people there," she says, "you move to another room and turn on another AC."

We head east. Street trees are scarce, and heat radiates off sidewalks, buildings, and the engine blocks and exhaust pipes of cars, buses, trucks, and construction vehicles that creep along 125th Street, which connects to several highways and bridges. Jessel and I pass weed-filled lots, commuters fanning themselves at unshaded bus stops, and shops shuttered since long before the pandemic. "It tears the neighborhood apart to have these spaces vacant," Jessel says.

It also may make residents more vulnerable to heat: When New York University sociologist Eric Klinenberg studied Chicago's 1995 heat wave, in which more than 700 died, he discovered that low-income neighborhoods with vibrant public spaces and plenty of commercial activity had fewer heat-related deaths. People in less animated neighborhoods were far less likely to step outside for relief or visit with caring neighbors, he surmised, because they didn't know one another, had few places to go, and were sometimes scared to walk the streets. And so they stayed inside—often with windows closed to guard against burglars—sweltered, and died.

IF WE IMPROVE THE LIVES OF THE MOST VULNERABLE AMONG US, **WE ALSO WILL IMPROVE OUR RESILIENCE TO EXTREME HEAT.**

Like many cities around the world, New York operates several dozen cooling centers: libraries, schools, senior centers, and other buildings that open their doors to the public during heat waves. In New York the centers are closed at night, and many people who might find relief in such places aren't aware they exist. Some refuse to visit them for fear their empty apartments will be burgled, as Klinenberg found in Chicago. In Phoenix, homeless people would rather roast in tent cities on asphalt parking lots than leave their worldly goods behind while seeking indoor relief, says Ash Uss, advocacy coordinator of that city's André House of Hospitality.

Getting people into those air-conditioned spaces will save lives, as ASU's David Hondula noted. But reducing social isolation may be equally important. In New York, Black residents die of heat-related causes at twice the rate that white ones do, but whites succumb at three times the rate of Hispanics and five times the rate of Asians—in part perhaps because whites are more likely to live alone.

BALOCHISTAN, PAKISTAN

Devotees making the arduous Hinglaj, a Hindu pilgrimage through the desert of western Pakistan, often faint in the extreme heat—104°F when this picture was taken. As body temperature rises, the heart works harder to pump blood to the skin. If it can't keep up, blood pressure plummets. Risk is highest for the elderly.

MATTHIEU PALEY

Coping with extreme heat is more complicated than it sounds because it's a nested problem, inseparable from larger social issues. But that's also its silver lining: If we improve the lives of the most vulnerable among us, we also will improve our resilience to extreme heat.

THE EUROPEAN HEAT WAVE of 2003 was a watershed event. It triggered national reckonings, endless finger-pointing, and major reforms. Within a year, France mandated "cool rooms" in previously un-air-conditioned nursing homes, launched telephone check-in systems for the vulnerable, beefed up heat-warning systems, and inaugurated a massive public education campaign on preventing heatstroke. When high temperatures returned, such measures were credited with reducing mortality 10-fold.

We know for certain that high temperatures will keep returning and that air conditioners alone won't eliminate all heat deaths. People still need and want to go outside.

And so in hot cities around the world, crews are planting shade trees and creeping vines to block sunlight. They're painting rooftops; installing rooftop gardens; erecting shade structures on sidewalks and in parks; hooking up misters and spray showers in playgrounds; and experimenting with roughly textured permeable pavement, which cools surrounding air by absorbing and then evaporating rainwater. In New York City, researchers from Columbia University's Earth Institute calculated that planting trees over

DASHT-E LUT, IRAN

Nomads make camp in the Lut Desert, which isn't as lifeless as it looks. Scientists hypothesize that the carcasses of migratory birds—which regularly fly off course and die here—provide sustenance for foxes, geckos, and locusts.

MATTHIEU PALEY

17 percent of the city's land surface and treating all roofs to reflect, rather than absorb, solar radiation could lower the city's overall temperature by 1.6 degrees Fahrenheit, or nearly a degree Celsius.

"We don't know if these tools will be enough to survive another half degree [Celsius] of warming," let alone the projected three degrees (5.4 degrees F) by century's end, says Kristie Ebi, who studies the impact of global warming on human health at the University of Washington. "But doing nothing is certainly not sufficient."

Rethinking how we build will be key to surviving a warmer future. Up until the mid-20th century, most buildings were developed with the climate in mind. In warmer latitudes, architects incorporated transoms, cupolas, skylights, air shafts, and operable windows to promote cross ventilation and updrafts. Awnings, light-filtering screens, louvered shades, overhangs, and porches defended rooms against the sun. Ceiling fans, which use up to a thousand times less energy than a room air conditioner, were ubiquitous. But as the cachet and influence of modernist architecture—with its inoperable windows and curtain walls of aluminum and glass—spread from the U.S. and Europe around the globe, so did dependence on mechanical air-conditioning.

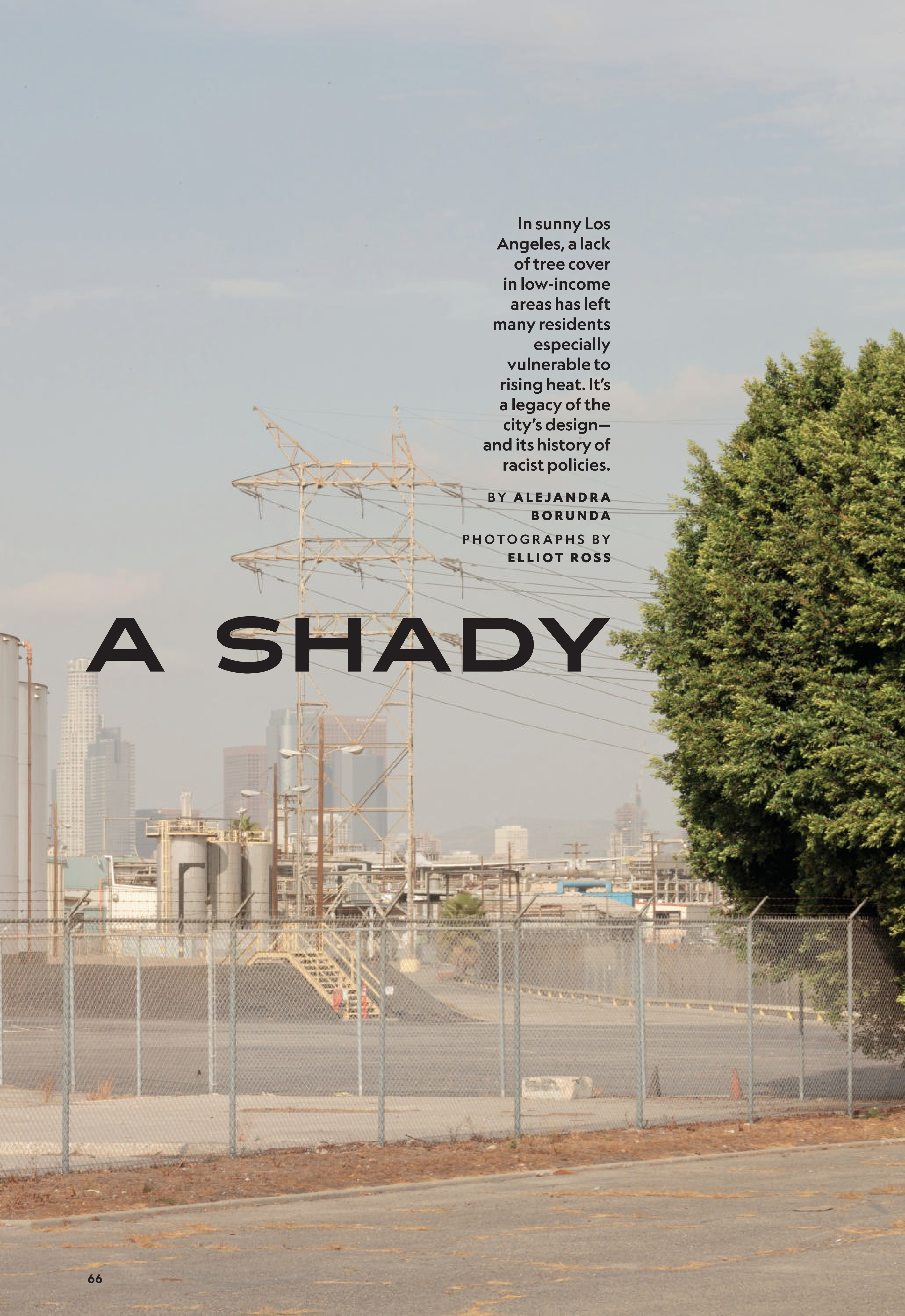
Climate-savvy architecture is starting to be a thing again. But we still have to live in the cities that are already built. We're not likely to tear down or substantially retrofit hundreds of thousands of poorly insulated, energy-intensive towers. Instead, suggests architect Daniel Barber, of the University of Pennsylvania, we might try to retrofit our expectations.

Now is the time, Barber says, to "condition ourselves to embrace, and even value, discomfort." Being a little too warm in summertime used to be something that even the affluent accepted, perhaps with the help of an iced beverage. Barber thinks we should learn to accept it again. In this paradigm the lavish chill of our conference rooms, or the "thermal delight" that greets the sweaty pedestrian as the doors to a high-end emporium whoosh open, would become artifacts of a fleeting late 20th-century insanity.

In Barber's vision, the energy-hogging global North, where excess comfort abounds, would transfer its ration of "thermal wealth" to the energy-impoverished global South, at least until we've given up fossil fuels. It would be a sort of comfort reparations—for having started climate change in the first place. "Architects already have the tools and knowledge to reduce our reliance on mechanical cooling," Barber says. Their project now is to make discomfort culturally desirable, even stylish.

Of course, style gets one only so far. Self-imposed discomfort will be a hard ethic to sell to a mass audience in wealthy countries, and even Barber—a provocateur with a serious point—recognizes the limits of the human body. "When it's 140 degrees, I hope to God I have an air conditioner, and that you do too," he says. "But when it's 85 out, please just open the window." □

A frequent contributor to *National Geographic* in print and online, **Elizabeth Royte** covers consumption and waste, food, and agriculture. She's the author of three books.



A SHADY

In sunny Los Angeles, a lack of tree cover in low-income areas has left many residents especially vulnerable to rising heat. It's a legacy of the city's design—and its history of racist policies.

BY **ALEJANDRA BORUNDA**

PHOTOGRAPHS BY **ELLIOT ROSS**

DIVIDE

M

MIGUEL VARGAS VIVIDLY REMEMBERS when he first understood the power of shade. He was in middle school, sprinting up and down a scrubby soccer field in Huntington Park, a small city laced with train tracks and high-voltage transmission lines just south of the Los Angeles skyline. He ran so hard in the battering sun that he overheated.

His vision went fuzzy. His heart pounded. In a daze he stumbled toward a towering red pine near the southwest corner of the field—the biggest and almost the only tree in sight.

In that shelter, Vargas's dizziness receded. His heart rate mellowed. He returned to himself, revived by the deep, cool shadow.

That simple blessing, he learned later when he took a job planting trees, is abundant elsewhere in L.A., primarily in rich, mostly white neighborhoods. But in predominantly Black and brown neighborhoods such as Huntington Park, which is 97 percent Hispanic, shade is vanishingly rare.

Los Angeles isn't Phoenix or Dallas. It has a moderate climate. But it too experiences deadly heat—and here, unlike almost any other U.S. city, it can strike year-round. Climate change is worsening the problem. It's already time to "turn off the sunshine," says L.A.'s chief design officer, Christopher Hawthorne. The city, he says, needs to find ways to build cooling, potentially lifesaving shade into its fabric.

MODERN LOS ANGELES is a city built on sunshine, not shadow. In the late 1800s and early 1900s, Southern California boosters enticed migrants from the East with visions of "almost everlasting sunlight." The allure of L.A.'s exceptional light has persisted, featured by Hollywood, celebrated by homegrown artists such as Robert Irwin. "On many days the world almost has *no* shadows," Irwin told the *New Yorker* in 1998. "Broad daylight—and in fact, lots and lots of light—and no shadows."

"Sunshine," says Hawthorne, "had become one of our central commodities."

The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded Explorer Elliot Ross's photographic work around the climate resilience of Indigenous communities in Alaska.

ILLUSTRATION BY JOE MCKENDRY

Los Angeles's car-centric design makes it seem as if the city is meant to be seen from an air-conditioned vehicle. Without much shade, pedestrians such as these at Vermont Avenue and Eighth Street, just west of downtown, often bake in the sun.

PREVIOUS PHOTO

A lone tree grows on a lot in Vernon, an industrial area near downtown L.A. where surfaces can be more than 15 degrees Fahrenheit hotter than in leafy neighborhoods. Only a hundred or so people live in this sun-blasted place, but some 50,000 come here to work.

Urban design in Los Angeles prioritizes access to the sun. The city code often defines where or for how much of the day a building can cast a shadow, lest it overly shade courtyards, parks, or patios. Architects have designed buildings to be transparent to sunlight and entire complexes to let it enter each corner. After the 1970s' energy crisis, the city had a new reason to ensure sun access everywhere; today, L.A. has more solar power capacity than any other American city.

But in the age of climate change, L.A.'s sunshine is no longer an unqualified boon. By mid-century, absent major international efforts to rein in carbon emissions, L.A. is expected to experience 22 days a year above 95 degrees Fahrenheit, more than triple the current number. The suburbs in the San Fernando Valley may see more than 90 days—a full quarter of the year. Heat already increases the risk of death in Los Angeles, even when it isn't the proximate cause. During a short heat wave, the death rate from all causes rises by 8 percent above normal. After four or five days, that number swells to 25 percent—and up to 48 percent among older Black and Latino residents.

"The really simple thing, if you care about making people more comfortable, is just to offer more opportunities for shade," says V. Kelly Turner, an urban planner at UCLA.

On a hot day you feel much hotter in the direct sun than in the shade, even if the air temperature is the same. That temperature is a measure of how fast air molecules are moving and are heating you as they bump into you—but solar radiation heats your body too. In direct sunlight you might feel as much as 20 degrees warmer than in nearby shade.

The same is true for buildings, sidewalks, and other massive objects: Direct solar radiation imparts more energy and therefore heat. Asphalt is a particularly good absorber, and along with concrete it releases that captured heat into the air for hours, even after the sun disappears, contributing to the urban heat island effect. A well-placed tree, on the other hand, can keep a building 18 degrees cooler than if it were fully exposed to the sun. Shade keeps everything cooler—and the overheating city is taking note.

WHEN SPANISH COLONIZERS arrived in the Los Angeles Basin, they found a landscape carefully managed by the Tongva and other Native inhabitants, a rich ecological patchwork with profuse pockets of shade. Forests of oaks and other trees meandered along the rivers and in the highlands that now make up East Los Angeles, providing shade and showers of nutritious acorns. A village called Yaangna, near today's downtown L.A., was "a very lush pleasing spot in every respect," wrote Father Juan Crespí, an early missionary who visited in 1679.

The Spanish felled many of the oaks for lumber and cleared other tree-dotted land for cattle. They created shade with buildings rather than trees: Streets were laid out roughly 45 degrees off of north-south, to maximize sun and shade exposure year-round, and long, arched loggias lined the external walls of missions and residences.

Settlers from the eastern U.S. reshuffled the shade landscape once again in the 19th century, planting new crops and citrus orchards. In the 20th century, using water siphoned from outside the Los Angeles Basin, they eventually created an "urban woodland," says Travis Longcore, an environmental scientist at UCLA. Especially after World War II, a neat single-family home with a car in the driveway and a pretty tree on the front lawn became the embodiment of the American Dream—and the booming L.A. population embraced it. Tree density grew by 150 percent from the 1920s to the early 2000s, when well over 10 million trees dotted the city.

But urban forests grow on money, which is not distributed equally. Most shade in Los Angeles fell on privately owned land, in places such as Los Feliz, Hollywood, or Brentwood, where people could afford trees and their often expensive care. Today, nearly 20 percent of the city's trees can be found in just five census blocks, home to just one percent of the population.

In contrast, trees did not sprout as readily in the poorer, Blacker, and browner parts of the city. Redlining in the first half of the 20th century had denied many people of color mortgage financing for the American Dream and had led to massive disinvestment in public goods, including trees. Public trees planted in such neighborhoods often were neglected by the underfunded forestry department, leaving residents to deal with broken branches, buckled sidewalks, and wilting greenery. Furthermore, to make way for cars, the city removed trees along streets and narrowed sidewalks. Trees were also felled or trimmed to allow street surveillance by L.A. police helicopters.

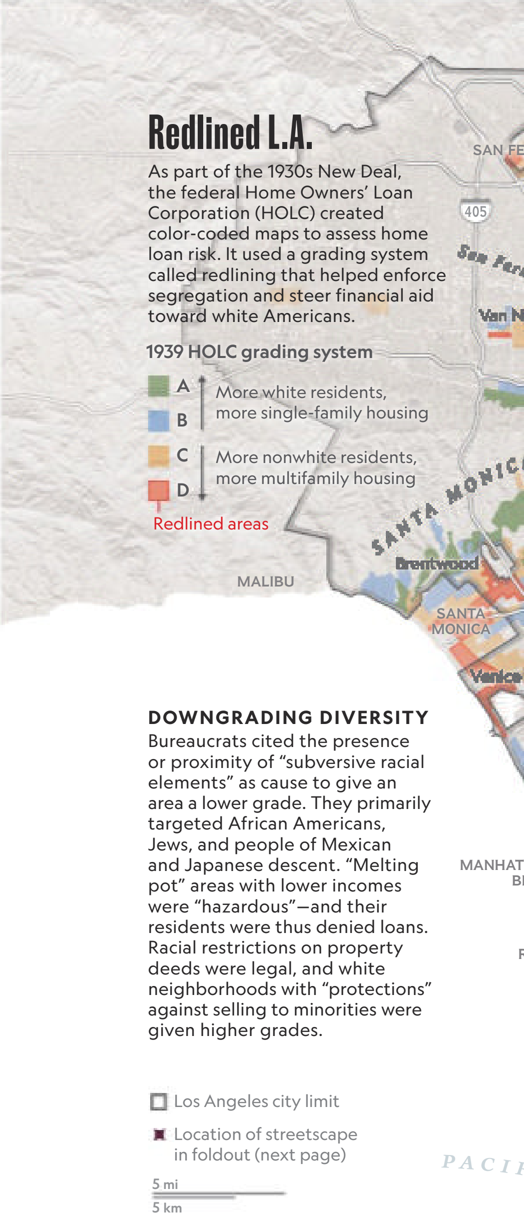
The disparity is stark: In some of the city's poorest neighborhoods, such as Huntington Park, trees shade well under 10 percent of the area, while in better-off places, such as Los Feliz, the canopy coverage can hit nearly 40 percent. That has a direct impact on public health. Formerly redlined neighborhoods are on average 7.6 degrees hotter than the richest ones.

"You just don't see green in the areas that were redlined," says Vivek Shandas, an urban ecologist at Portland State University who is advising L.A. on equitable tree planting.

On a few stretches of Vermont Avenue in Los Feliz, the roots of decades-old Moreton Bay figs fill eight-foot-wide tree wells on both sides of the quiet, divided roadway. Luxuriant branches meet over the 40-foot-wide median. Murky, cool light flickers to the grass below. But seven miles south on the same street, in South Central Los Angeles, the sun beats down unimpeded.

One day last winter, it shone on Rachel O'Leary and Cindy Chen, of a nonprofit called City Plants, who were looking for places to plant trees in South Central. On one

(Continued on page 82)



Redlined L.A.

As part of the 1930s New Deal, the federal Home Owners' Loan Corporation (HOLC) created color-coded maps to assess home loan risk. It used a grading system called redlining that helped enforce segregation and steer financial aid toward white Americans.

1939 HOLC grading system

🟩 A
🟦 B
More white residents, more single-family housing

🟧 C
🟥 D
More nonwhite residents, more multifamily housing

Redlined areas

DOWNGRADING DIVERSITY
Bureaucrats cited the presence or proximity of "subversive racial elements" as cause to give an area a lower grade. They primarily targeted African Americans, Jews, and people of Mexican and Japanese descent. "Melting pot" areas with lower incomes were "hazardous"—and their residents were thus denied loans. Racial restrictions on property deeds were legal, and white neighborhoods with "protections" against selling to minorities were given higher grades.

☐ Los Angeles city limit

▪ Location of streetscape in foldout (next page)

5 mi
5 km

HOW DISCRIMINATIO
SHAPED LOS ANGELES

For much of the 20th century, segrega
encouraged by the federal governme
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while, white residents received subsid
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values rose. Unequal access to loans a
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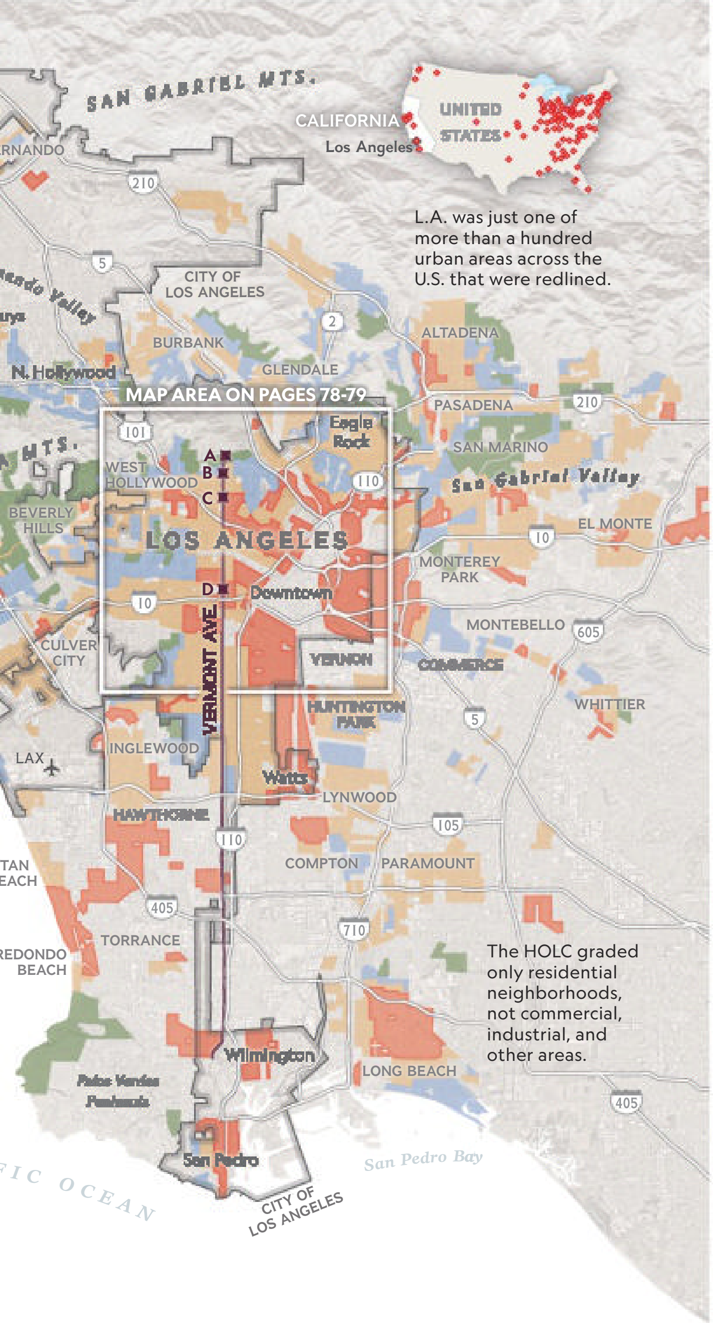
RILEY D. CHAMPINE, NGM STAFF. SOURCES: JEREMY S. HOFFMAN
RICHARD ROTHSTEIN, *THE COLOR OF LAW: A FORGOTTEN HISTO*



L.A. was just one of more than a hundred urban areas across the U.S. that were redlined.

The HOLC graded only residential neighborhoods, not commercial, industrial, and other areas.

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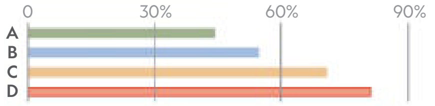
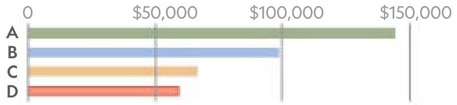
STILL SEGREGATED AND STRATIFIED

Redlining has been banned for 50 years, but its legacy—concentrating poverty and people of color in some areas and wealthy whites in others—lives on.

Nonwhite population in HOLC-graded areas, 2019



Median household income, 2019 (USD)



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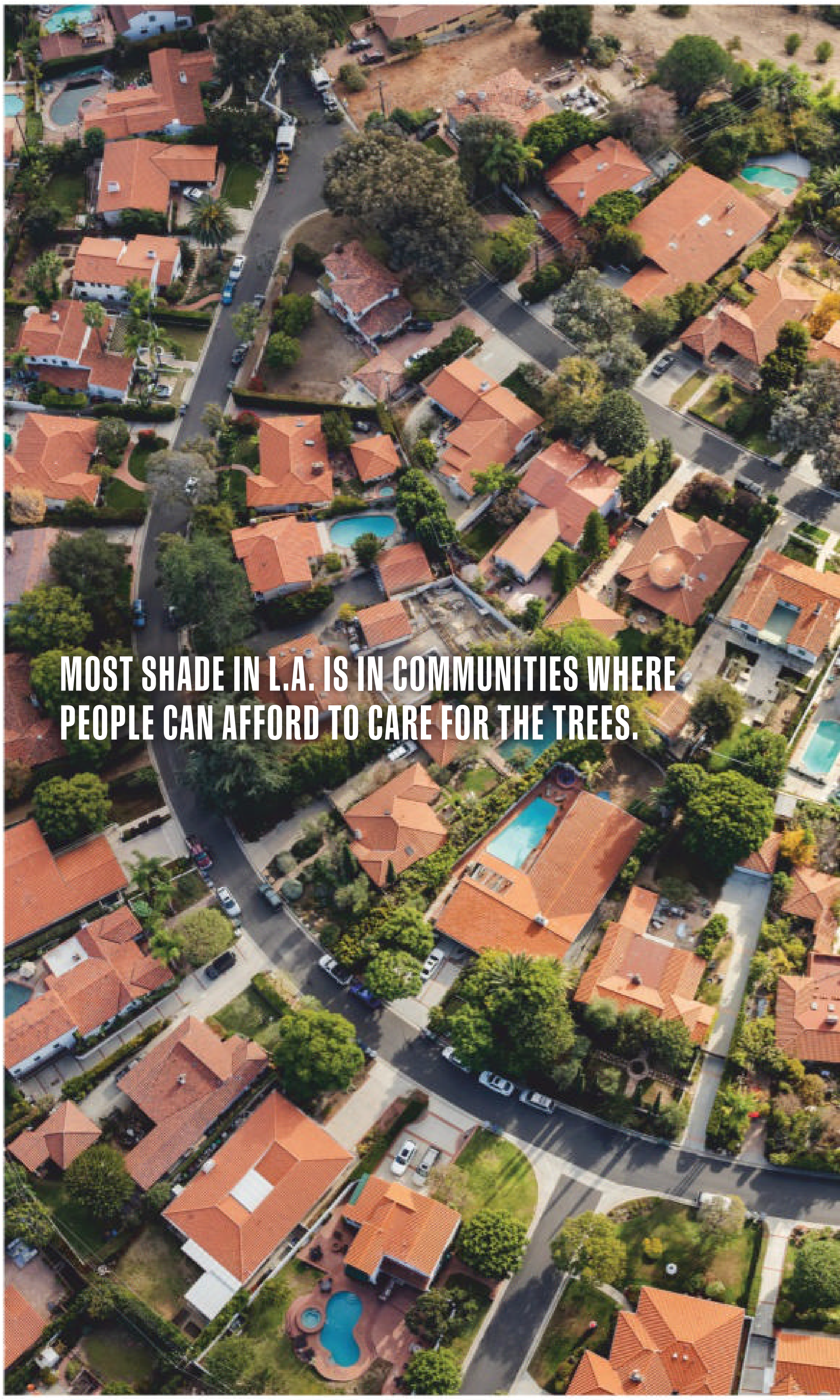
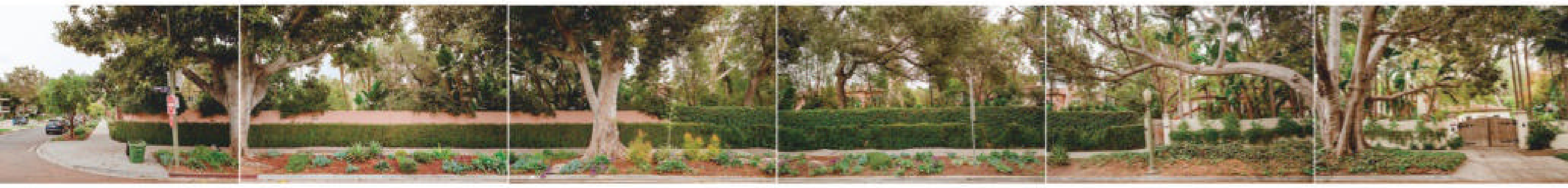
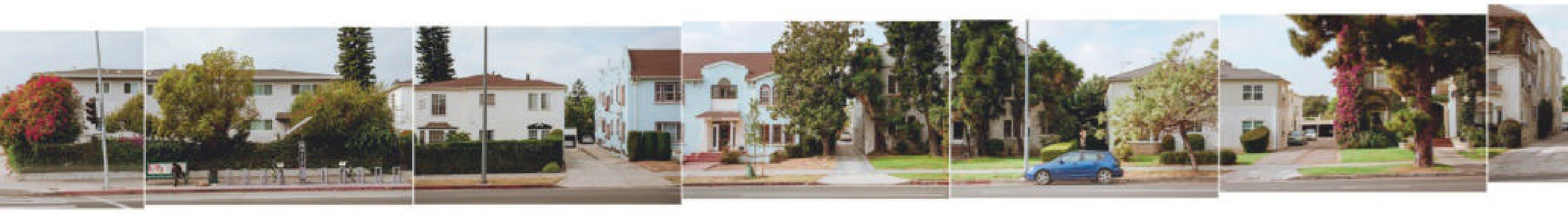


MOST SHADE IN L.A. IS IN COMMUNITIES WHERE PEOPLE CAN AFFORD TO CARE FOR THE TREES.

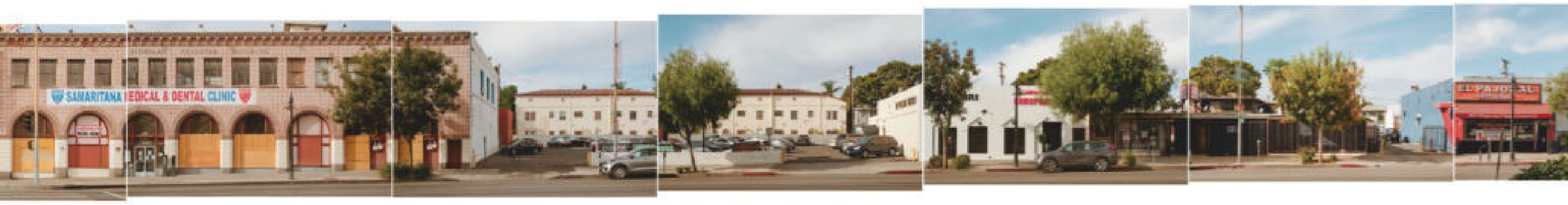
GRADE A, ROLLING HILLS



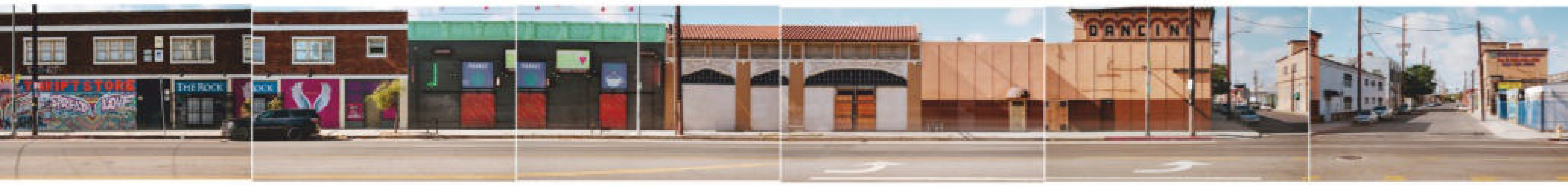
GRADE A, LOS FELIZ



GRADE B, LOS FELIZ



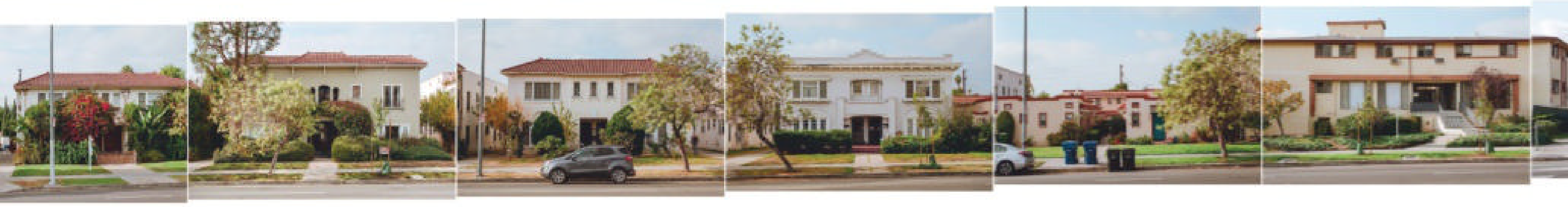
GRADE C, EAST HOLLYWOOD



GRADE D, PICO-UNION

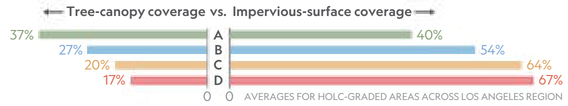
L.A.'S TREE CANOPY REFLECTS URBAN INEQUITY

Trees become sparser and neighborhoods hotter as you drive from north to south along Vermont Avenue. Over about six miles, the road passes through areas that show the enduring effects of housing discrimination through redlining, which ranked areas from A ("green," or most suitable for investment) to D ("red," or least suitable). At the north end, in Los Feliz, spreading fig trees line the avenue. In this and other affluent grade A areas, a 1939 map notes, deed restrictions left ownership of some houses "limited in perpetuity to Caucasian" buyers. Grade B was still "reasonably homogenous." But grade C was marked by "subversive racial elements" and potential "infiltration" from redlined grade D areas—such as the one near I-10 in Pico-Union. Today, trees are all but absent there, and average temperatures are notably hotter than they are six miles north.



OUT OF BALANCE

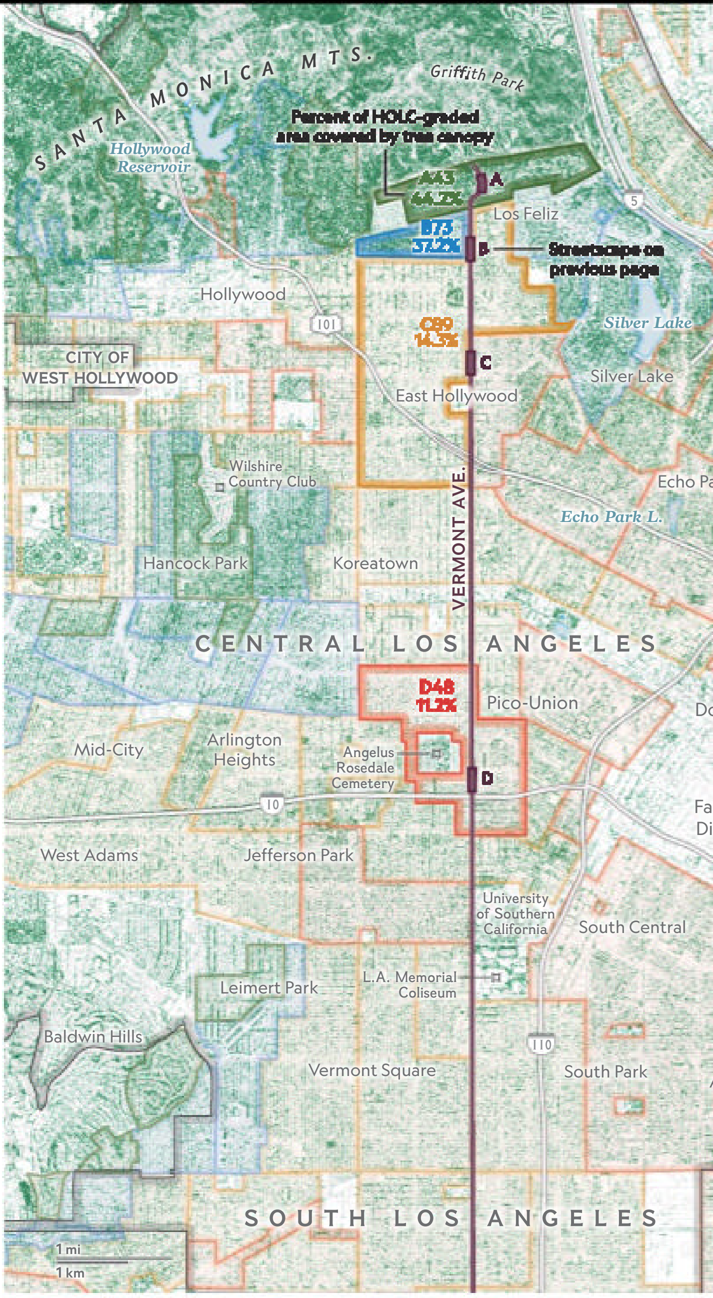
Grade A areas have about an equal amount of tree canopy and impervious surfaces or "hardscapes" (such as buildings and pavement). In grade D areas, hardscapes dominate the environment, leaving little room for large trees to mature.



RILEY D. CHAMPINE, THEODORE SICKLEY, NGM STAFF. SOURCES: UNIVERSITY OF RICHMOND DIGITAL SCHOLARSHIP LAB; EPA

IN LOW-INCOME, LARGELY MINORITY AREAS, LACK OF PUBLIC INVESTMENT MEANS FEWER TREES.

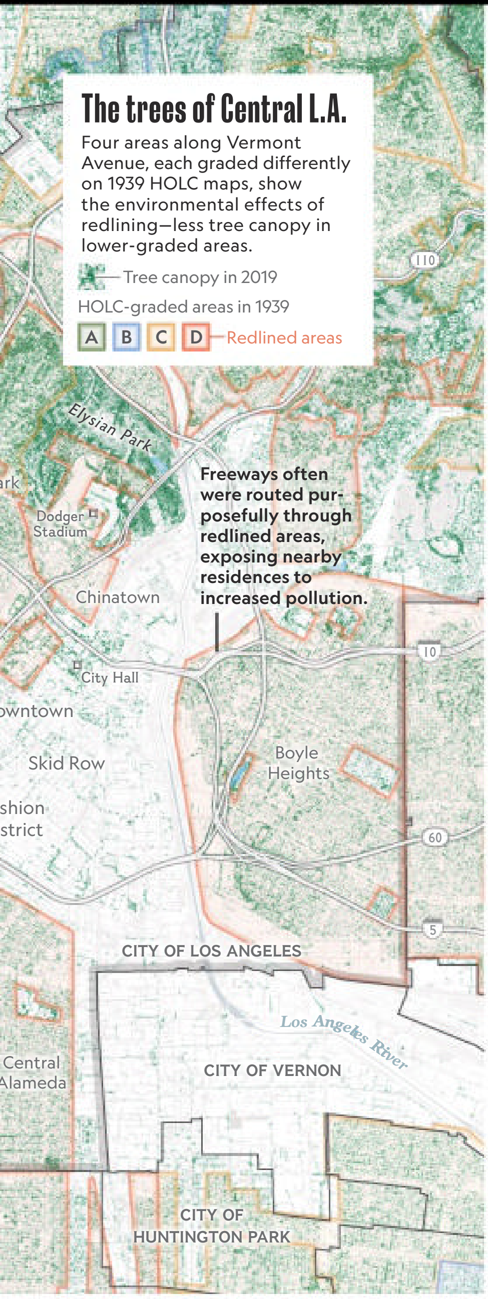
GRADE D, HAWTHORNE



AN URBAN CANOPY CAN HELP COOL A CITY

A city's tree canopy can be considered infrastructure, much like a sewer system or street grid. A developed canopy can mitigate the "urban heat island" effect, in which pavement and buildings trap heat and raise temperatures well above those found in natural landscapes outside the city. But maintaining a lush urban forest takes time and resources, especially in a dry climate like that of Los Angeles, where irrigation is costly.

DIAN



The trees of Central L.A.

Four areas along Vermont Avenue, each graded differently on 1939 HOLC maps, show the environmental effects of redlining—less tree canopy in lower-graded areas.

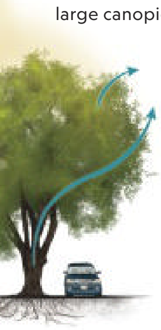
🟩 Tree canopy in 2019

HOLC-graded areas in 1939

A B C D Redlined areas

Freeways often were routed purposefully through redlined areas, exposing nearby residences to increased pollution.

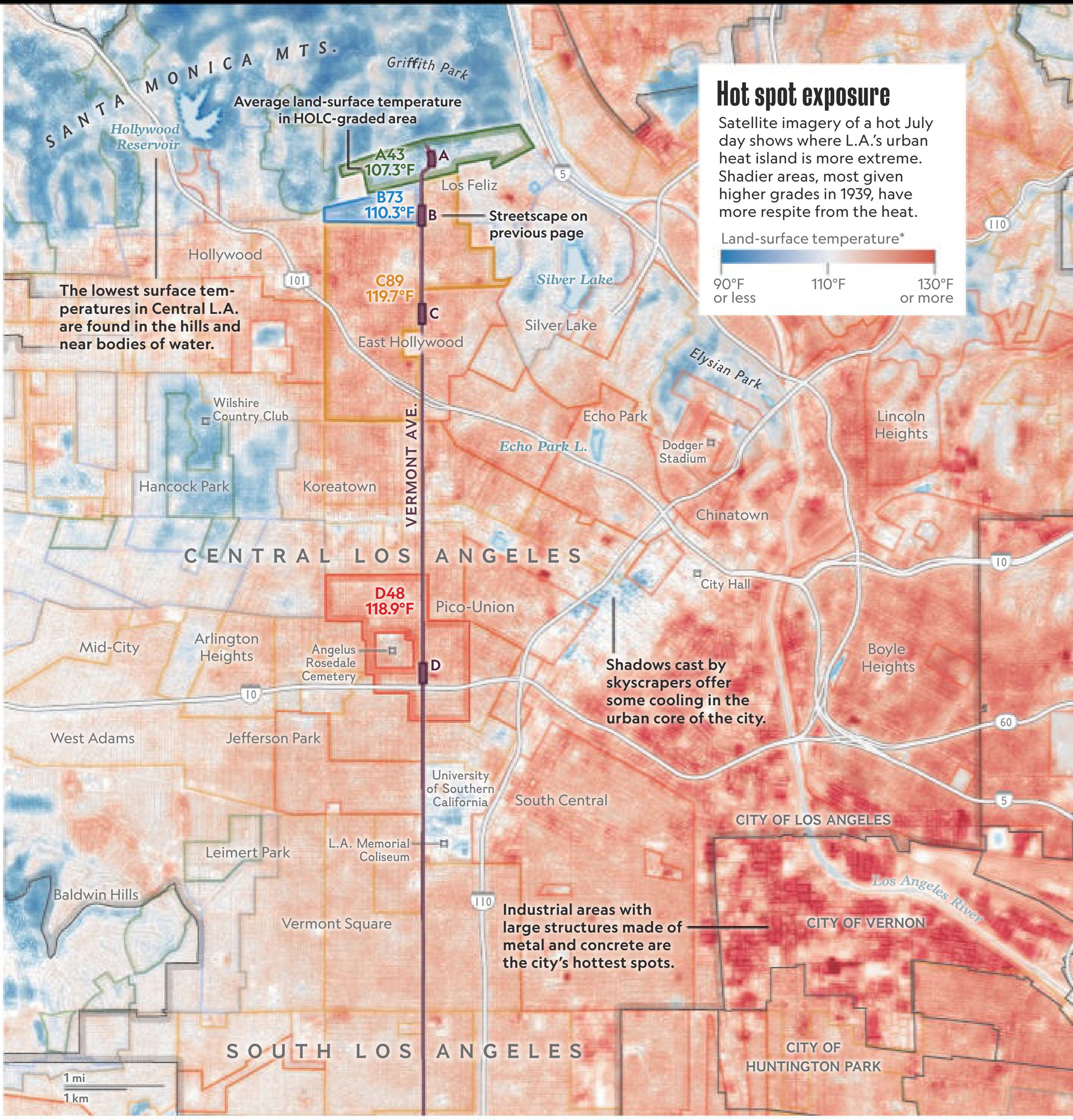
An effective urban forest has a variety of climate-resilient tree species, with large canopies and dense foliage.



Rain or groundwater evaporating from trees can lower air temperatures by up to 9°F.

Shading objects from solar rays can lower their surface temperature by up to 45°F on a hot day.

NA MARQUES, NGM STAFF. SOURCE: YUJUAN CHEN, TREEPEOPLE



Hot spot exposure

Satellite imagery of a hot July day shows where L.A.'s urban heat island is more extreme. Shadier areas, most given higher grades in 1939, have more respite from the heat.

Land-surface temperature*

90°F or less | 110°F | 130°F or more

Average land-surface temperature in HOLC-graded area

The lowest surface temperatures in Central L.A. are found in the hills and near bodies of water.

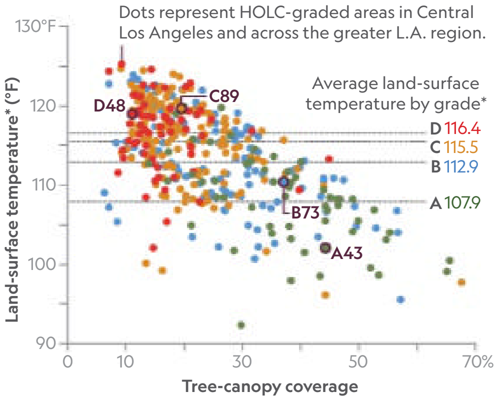
Streetscape on previous page

Shadows cast by skyscrapers offer some cooling in the urban core of the city.

Industrial areas with large structures made of metal and concrete are the city's hottest spots.

BUT SHADE CAN BE HARD TO FIND IN MUCH OF L.A.

As Los Angeles experiences more extremely hot days because of climate change, the urban canopy's capacity to lower temperatures can be a lifesaver. Today, however, L.A.'s tree canopy is mostly developed in areas where residents are more likely to be white and rich. In poorer neighborhoods that were redlined and neglected—and where there are still more people of color—this protection from deadly heat is missing.

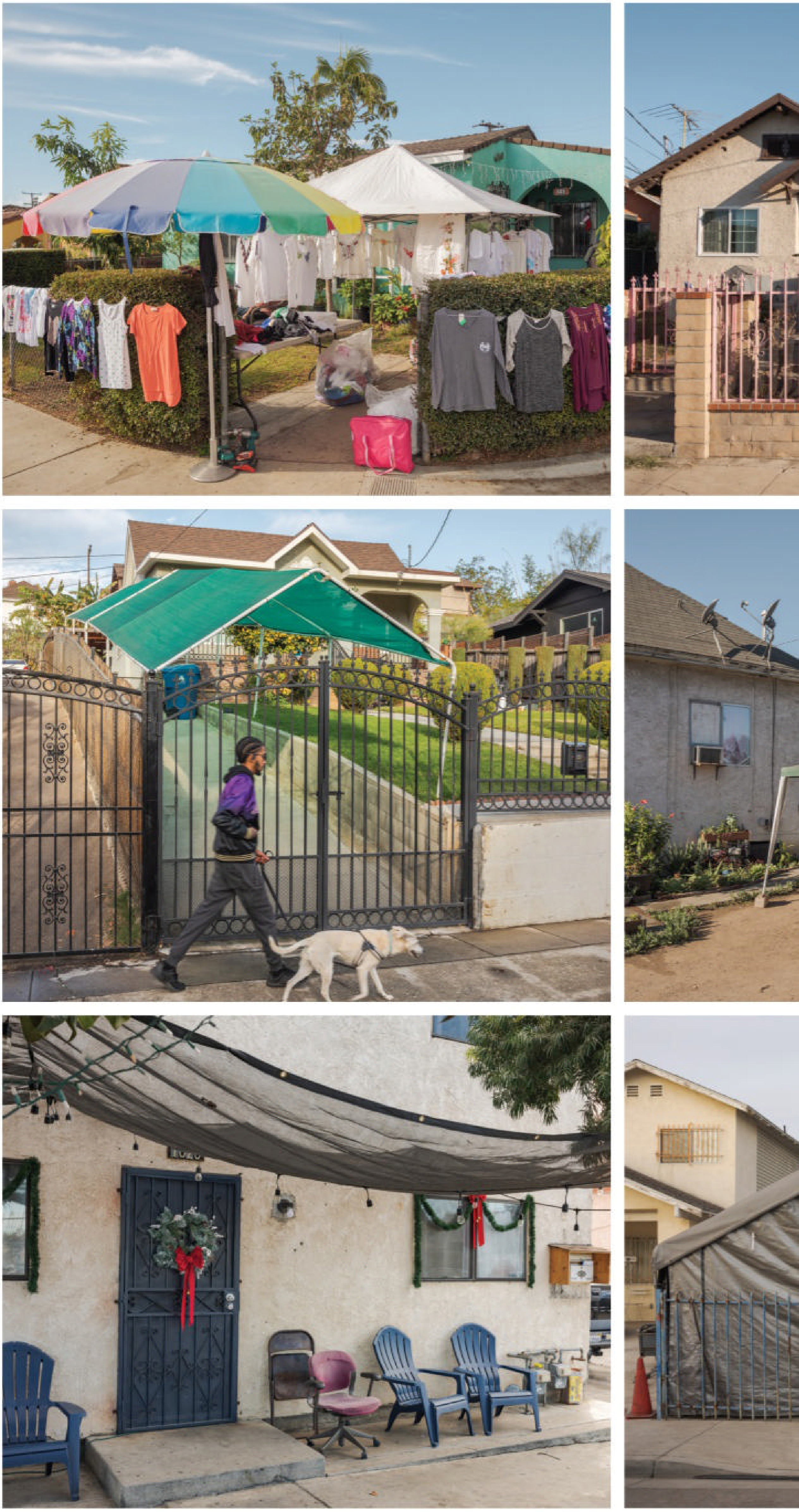


Dots represent HOLC-graded areas in Central Los Angeles and across the greater L.A. region.

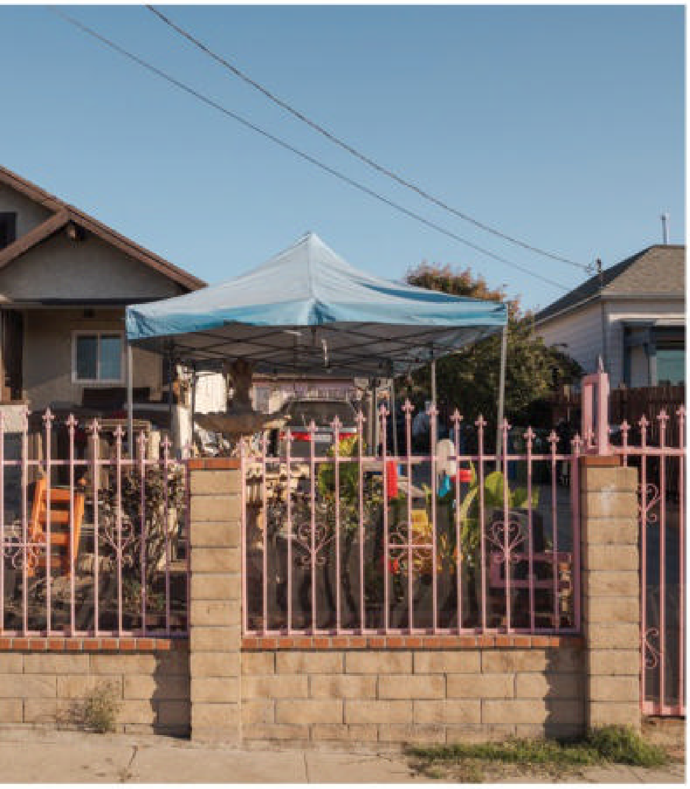
Average land-surface temperature by grade*

RILEY D. CHAMPINE, THEODORE SICKLEY, NGM STAFF. SOURCES: JEREMY S. HOFFMAN, SCIENCE MUSEUM OF VIRGINIA; UNIVERSITY OF RICHMOND DIGITAL SCHOLARSHIP LAB; U.S. CENSUS BUREAU; EPA; NASA

*AVERAGE LAND-SURFACE TEMPERATURE ON JULY 3, 2020



Many L.A. residents, particularly in Latino neighborhoods, have mastered the art of homemade shade solutions, says urban planner James Rojas. The defining aesthetic is *rasquachismo,* a Chicano term for resourceful, cheerful cobbling together of whatever is around to create something vibrant and functional. Houses in the region often lack central air-conditioning or good ventilation, so access to comfortable outdoor spaces is essential.



L.A. IS NOT ALONE

Baltimore, Maryland, is also hiring residents to plant trees in underserved communities.

Phoenix, Arizona, is targeting the hottest neighborhoods—low income and primarily Hispanic—for tree planting, shade structures, and redesigned streets.

Boston, Massachusetts, is one of many cities that have created sophisticated shade maps to drive future planning efforts.

For more stories about how to help the planet, go to *natgeo.com/planet*.

Ladale Hayes plants a pink trumpet tree in Watts, part of an L.A. campaign to plant 90,000 trees by the end of 2021—and many more after that. Working for North East Trees, a nonprofit, Hayes leads a team of young adults, most of whom are planting in the neighborhoods where they live. The trees will require years of care before their shade provides relief.

(Continued from page 70) long block with 33 residential lots, they found just nine street trees. Six were so immature, they cast only a dollop of shade. A white mutt soaked in the cool under an overtrimmed jacaranda; construction workers rested under two fat-trunked figs. The rest of the block was open to the sun.

Chen has built a computer model that finds the little wedges of land where the city could add trees, a trickier proposition than it sounds. Of the 88,500 square feet of publicly managed land on this block (including the street), only about 10,800 square feet are even potentially plantable. Chen's model picked out places that couldn't fit trees because of driveways, fire hydrants, alleys, and other obstacles such as water and gas meters or power poles. What was left was enough space, in three-foot-wide strips along the narrow sidewalks, for 16 more street trees.

That's not a lot, O'Leary admits. But this area currently has less than 3 percent canopy cover. "Some trees are better than no trees," she says.

LOS ANGELES AIMS TO PLANT 90,000 more trees by the end of 2021, with the goal of increasing canopy cover by 50 percent by 2028 in neglected neighborhoods like South Central. The campaign is far from a panacea, the city's forest officer, Rachel Malarich, says bluntly. Trees take years if not decades to mature and require significant watering. But their benefits, she says, far outweigh the costs.

Christopher Hawthorne is advocating a holistic approach that integrates shade considerations

into all public urban design decisions in L.A. “Rather than embracing sun and sunshine,” he says, “we need to start thinking about designs that could protect us from sun and heat.”

At the broadest scale, that would entail reorienting the city itself away from cars, returning space to pedestrians—and trees. It might mean narrowing streets and allowing them to be shaded by taller buildings than current codes permit. There are laws governing the right to heat in buildings, and in Europe even to sunlight; maybe it’s time to assert a right to shade and cool, Hawthorne says.

For now, the city is starting small. In a design competition to reimagine streetlights, contestants had to make them do double or triple duty—provide light, add shade if they could, and perhaps host art. Bus shelters are next up for a redesign, and even before then the city is working on adding 750 shelters at heavily used stops on the hottest streets. At UCLA, engineer Aaswath Raman is developing optical materials that shoot the sun’s incoming energy back out to space; a shelter made of such material would not only block the sun, it would cool the air beneath it.

Any shade from any source would be more than welcome, Esmerita Gómez says as she waits for a bus at the corner of Vermont Avenue and Venice Boulevard near downtown L.A. “There were three trees here once. But they cut it down.” She stands carefully in the narrow shadow of a telephone pole until the bus groans to a stop in front of her.

Finding or making shade is a well-honed skill for Latino residents of the city, says James Rojas, a city planner who grew up in East L.A. Take the patios, porches, and yards of Boyle Heights: They’re a *rasquache* pastiche of creative shade solutions. Bamboo mats tied to wrought-iron fences. Faded umbrellas lashed into place and colliding with bougainvillea-laced trellises. Tarps strung in elegant, overlapping swoops—“to protect *mi padre y la Virgen de Guadalupe,*” says Gubernal Velasquez, gesturing from under a neat white awning toward his aging father and a nearly life-size religious icon, both in deep shade. These are design solutions born out of necessity, Rojas says, that the city can learn from and encourage while waiting for the tree canopy to grow in or the city itself to be reshaped.

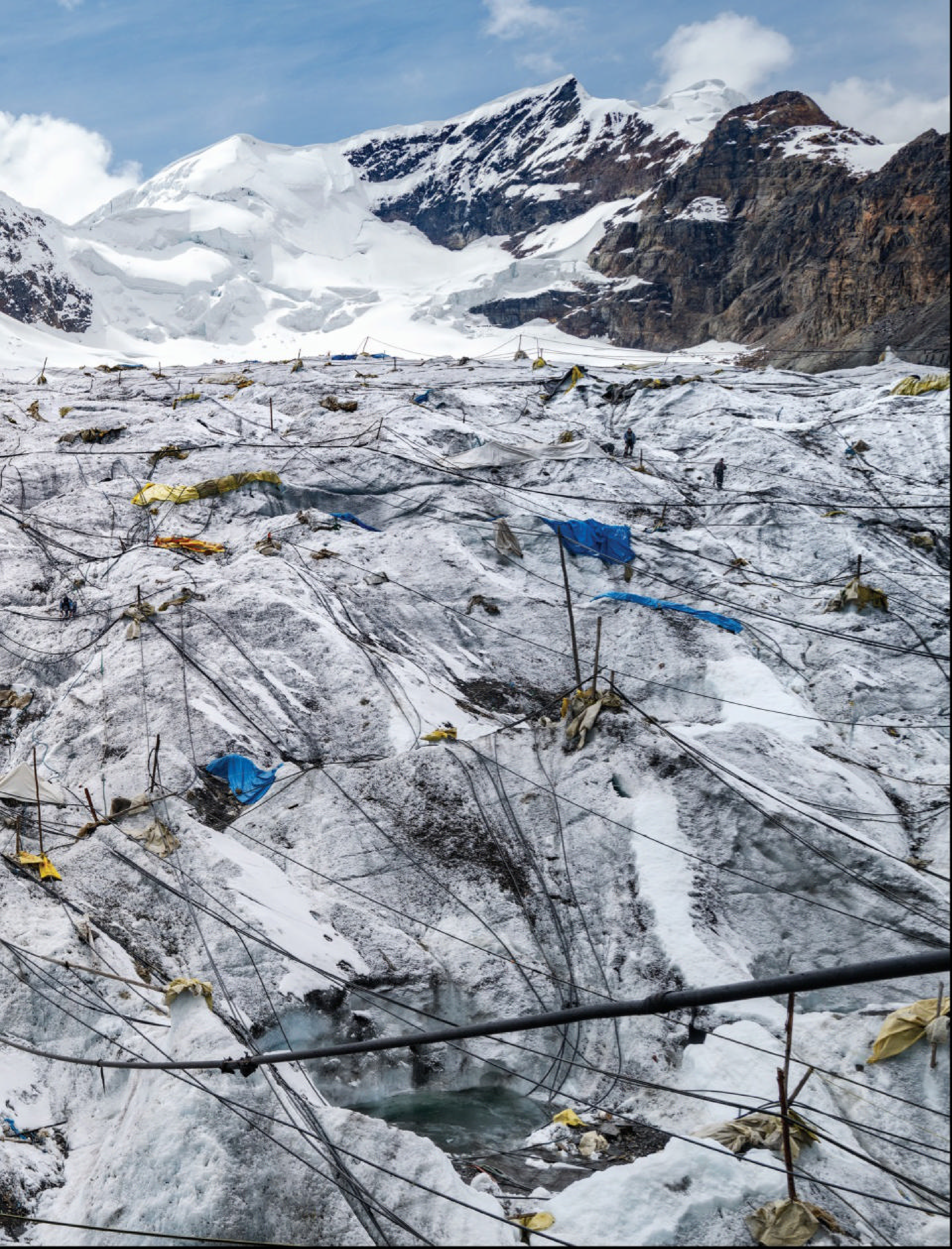
Vargas, the tree planter, takes the long view. He knows the value of a moment of shade, and he knows that it matters even more for the *abuelitas* in his neighborhood walking to pick up their grandchildren; for the domestic workers walking to the bus stop in the sweltering summer; for everyone who doesn’t have an air conditioner. A bead of sweat rolls down his cheek as he digs a hole for a spindly crape myrtle, one of 1,400 new trees he’s helped plant in Huntington Park, his hometown in southern Los Angeles County.

“This is not a short-term thing. We won’t feel the effects this year, next year, maybe not even in 10 years. The people who are going to feel it are the next generation,” he says. “Slowly but surely, we’ll get there so it’s less hot throughout the projects.” □

Staff writer **Alejandra Borunda** covers climate change and efforts to adapt to it. Colorado-based photographer **Elliot Ross** focuses on the American condition and spaces in transition.

THE WORLD'S HIGHEST

IN THE PERUVIAN ANDES, DESPERATION FUELS A DANGEROUS, TOXIC



GOLD RUSH

HUNT FOR THE PRECIOUS METAL.

BY **BARBARA FRASER**
AND **HILDEGARD WILLER**

PHOTOGRAPHS BY
CÉDRIC GERBEHAYE

THREE MILES UP IN THE PERUVIAN ANDES, LA RINCONADA IS THE HIGHEST SETTLEMENT ON THE PLANET,

a place whose bleak existence depends on the high price of its most coveted resource—gold.

As the price of the precious element more than quintupled over the past two decades, what was once a small town in the shadow of snowcapped Mount Ananea has transformed into an uncontrolled sprawl of corrugated metal shacks packed around artisanal mine entrances and a refuse-choked lake. The biting cold and lack of oxygen at 16,732 feet above sea level leave even the locals gasping for breath, and it smells like what it is—a settlement with a transient population of some 30,000 to 50,000 people and no garbage collection or sewer system.

Fatal accidents in the labyrinth of mines deep inside Mount Ananea are common, as are lethal brawls. Miners have been robbed or even murdered after selling their gold, their bodies left in mine shafts. Some murder victims have been women and girls lured from larger cities in Peru and Bolivia by human traffickers who confiscated

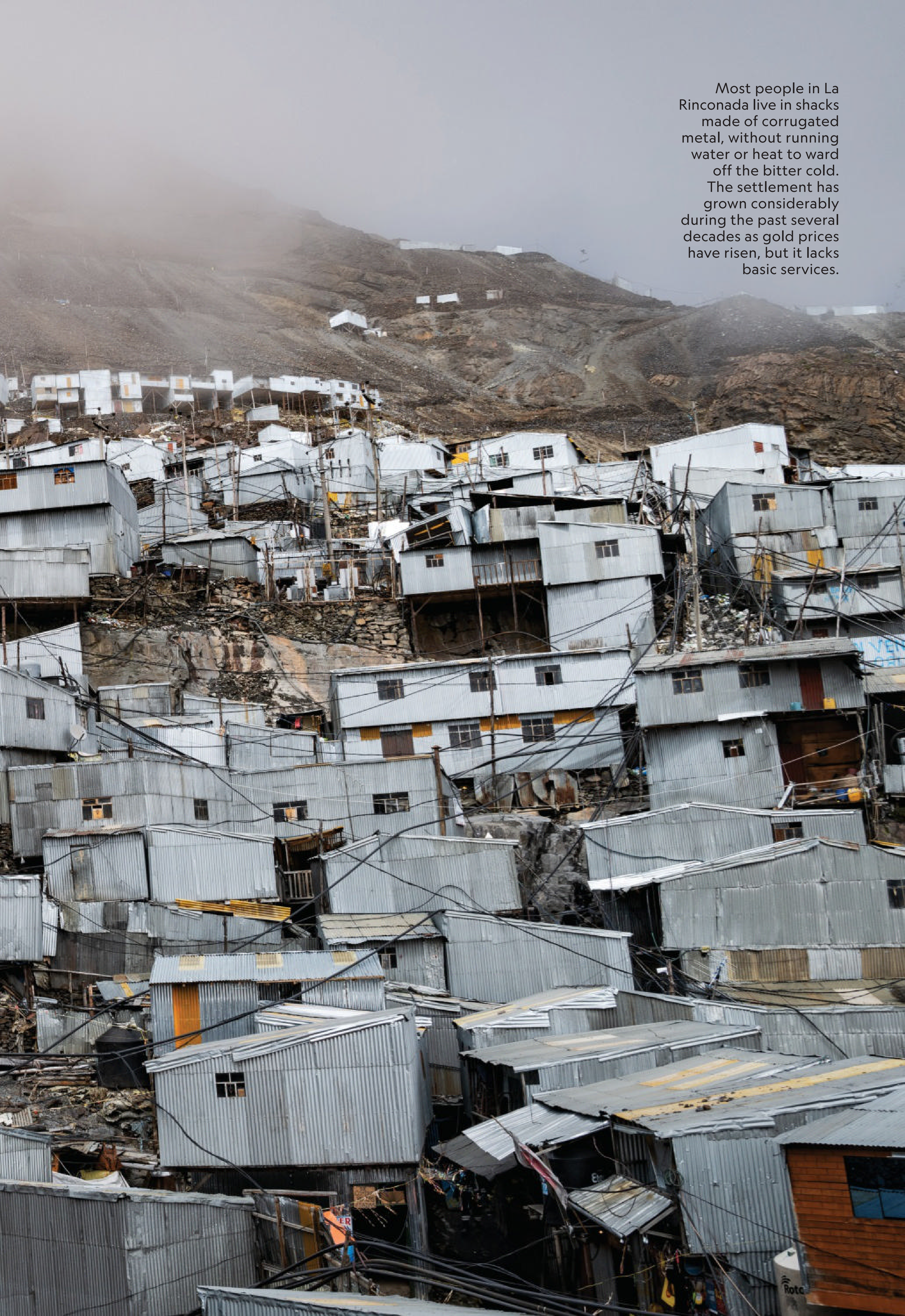
LEFT

A miner known as a *lamero* carries, and is covered by, *lama*—muddy ore tailings left after mercury processing—that will be reprocessed with cyanide to extract more gold (shown above). Exposure to toxic fumes affects the nervous, digestive, and immune systems, damages the lungs, kidneys, and heart, and eventually can be fatal.

PREVIOUS PHOTO

Mercury vapor from gold processing in La Rinconada contaminates the nearby glacier called Sleeping Beauty and, as a result, the water that residents use for drinking and cooking. Workers on the glacier adjust hoses that channel meltwater to the Peruvian mining settlement.

EN
VENTA
3 CUARTO



Most people in La Rinconada live in shacks made of corrugated metal, without running water or heat to ward off the bitter cold. The settlement has grown considerably during the past several decades as gold prices have risen, but it lacks basic services.

their identity papers and put them to work in La Rinconada's dingy bars and brothels.

Several small companies have claims in Mount Ananea, and one contracts out sections of its claim to around 450 members of cooperatives who are among its shareholders.

Most of the mines operating under those contracts are considered informal—meaning they have substandard labor, safety, and environmental conditions but are allowed by the government to continue operating as long as they register with a program that's aimed at bringing them into compliance with higher standards.

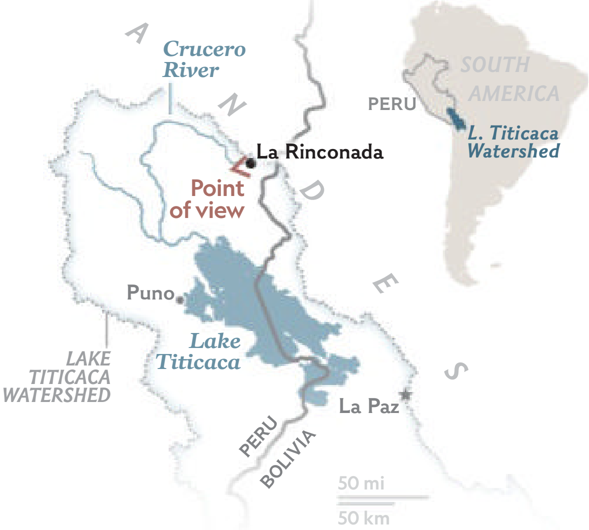
The conditions in La Rinconada harm workers' health and poison the Andean landscape, but that hasn't stopped buyers and refiners in the United States, Switzerland, and other countries from purchasing La Rinconada's gold, processing it, and turning it into bullion and brilliant jewelry. By that time, the gold bears no indication of its origin in poorly regulated Peruvian mines. International efforts to fetch better prices for gold from mines that meet higher standards have made no inroads in La Rinconada.

The irony of La Rinconada's modern gold rush is not lost on Víctor Hugo Pachas, a Peruvian anthropologist who studies unregulated gold mining in Peru and other South American countries.

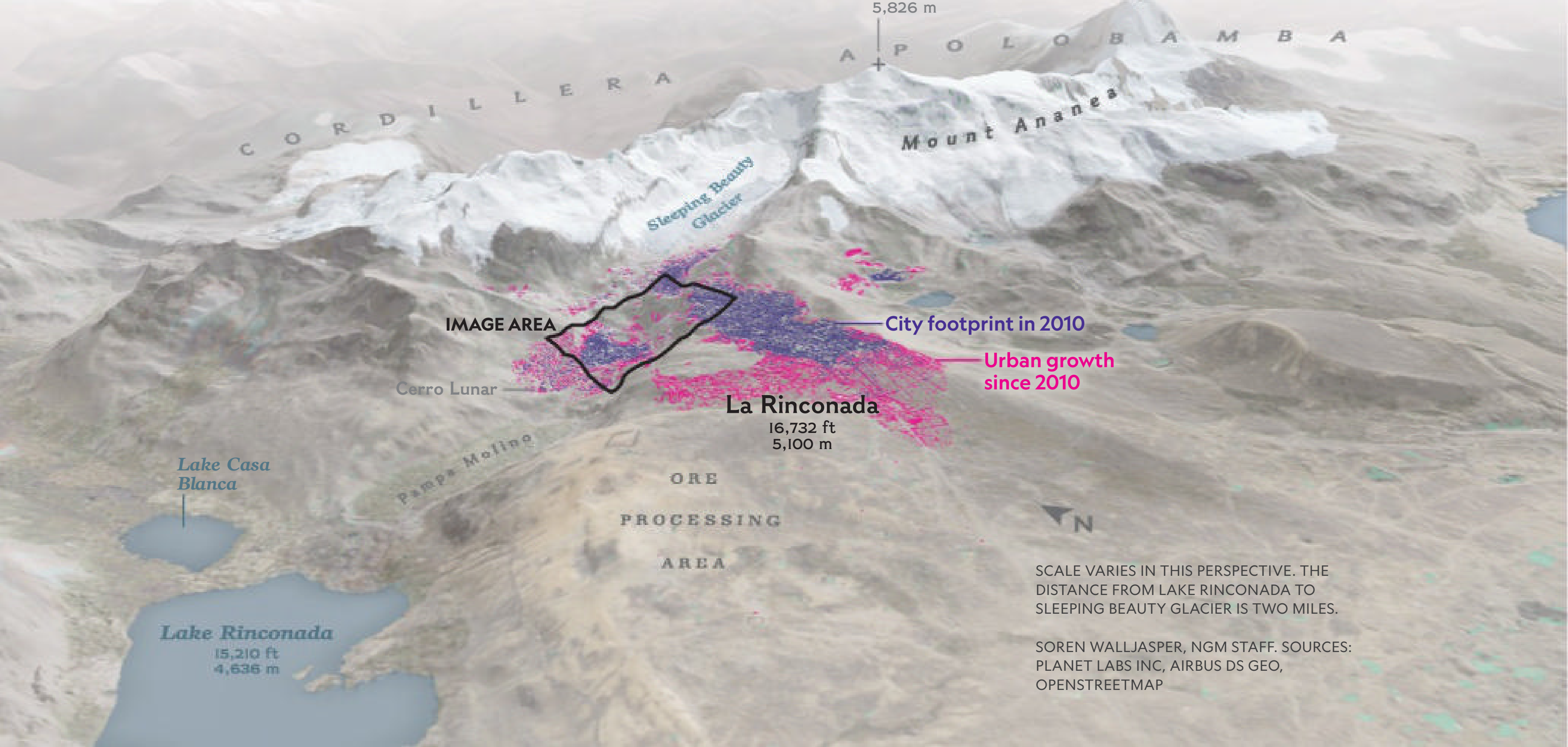
"Small-scale mining like that in La Rinconada has always existed in the Andes as a secondary

THIN AIR, DANGEROUS TERRAIN

La Rinconada is the world's highest settlement. At 16,732 feet—almost as high as Base Camp at Mount Everest—La Rinconada's meager oxygen levels and treacherous terrain make life difficult. Yet La Rinconada has grown rapidly in the past three decades as gold prices have risen. Pollution from gold processing settles on glaciers that form the Andean water system's headwaters, sending toxic chemicals such as mercury far downstream.

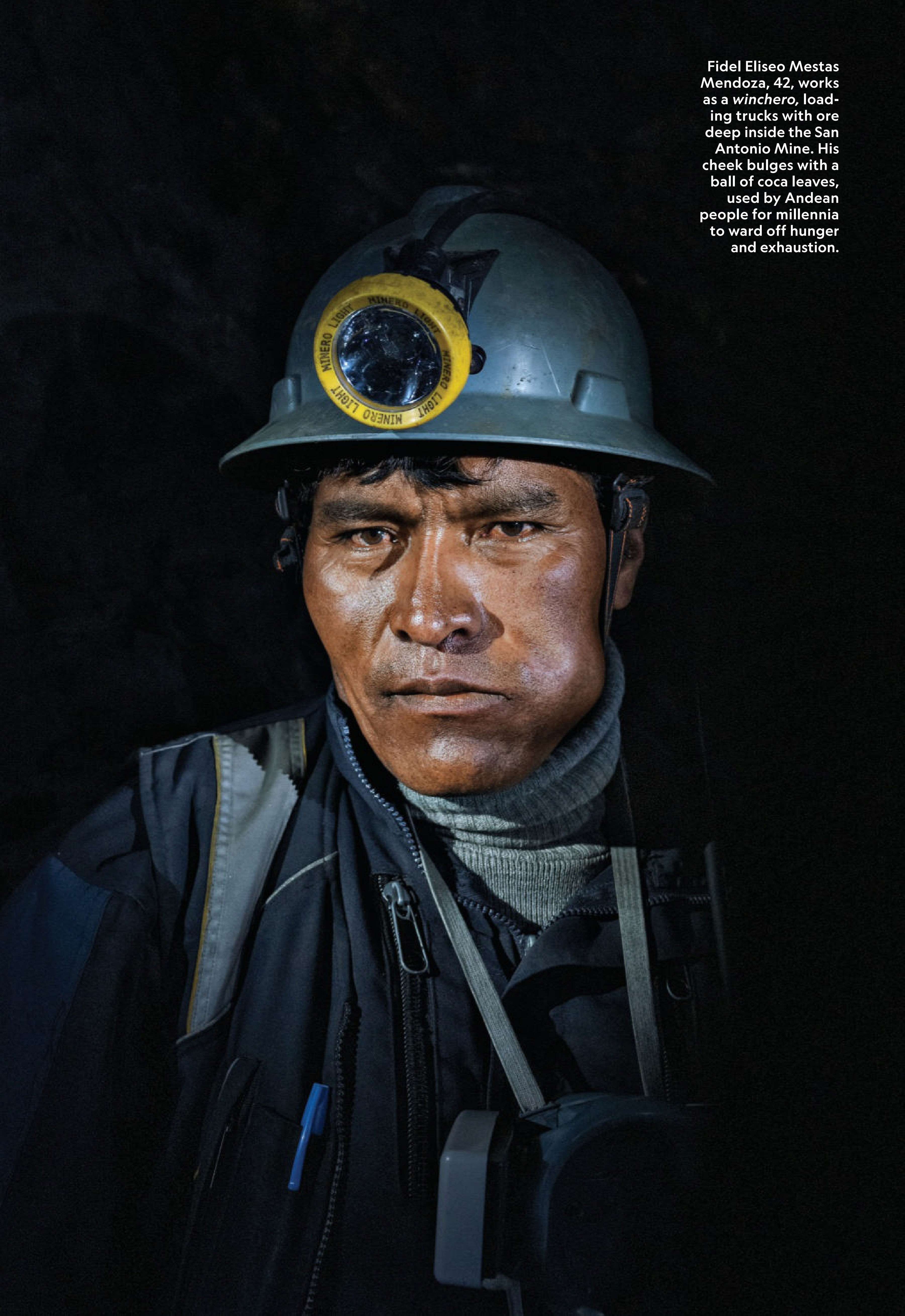


La Rinconada's buildings are densely packed between steep cliffs.



SCALE VARIES IN THIS PERSPECTIVE. THE DISTANCE FROM LAKE RINCONADA TO SLEEPING BEAUTY GLACIER IS TWO MILES.

SOREN WALLJASPER, NGM STAFF. SOURCES: PLANET LABS INC, AIRBUS DS GEO, OPENSTREETMAP



Fidel Eliseo Mestas Mendoza, 42, works as a *winchero,* loading trucks with ore deep inside the San Antonio Mine. His cheek bulges with a ball of coca leaves, used by Andean people for millennia to ward off hunger and exhaustion.

activity—farmers or ranchers would go to the mines periodically to supplement their farm income," Pachas says of a practice that dates to at least the early 19th century in Peru's Puno region, where La Rinconada is located.

Miners always complain that the mines are playing out, he says, "but there's still gold. If there comes a time when there is less gold, mining will again become a complementary activity for farmers, as it was before."

THE CONTRACTORS who operate the informal mines often live outside of La Rinconada, leaving day-to-day operations to a trusted overseer. That person manages laborers who mine the ore with nothing more sophisticated than dynamite and pneumatic drills. Small-scale processing plants crush the ore and mix it with mercury or cyanide to extract gold. Then a chain of brokers buy and sell the gold and, in some cases, export it.

Labor agreements generally are verbal, with a foreman hiring workers for a week to several months, depending on the gold vein being worked. The laborers may receive food and lodging but no benefits or wages. Instead, for roughly a day or two a month they are allowed to work in the mine and keep what they find, a system known as *cachorreo*. If they find nothing, it means they've worked for free.

Miners grumble about the system, but no one really wants to change it—it's cheaper for the contractor, and it's easier for a laborer to leave if he decides he's had enough. Many stay, however,

A woman rocks on a stone *quimbalete* to crush gold-bearing ore she scavenged that day. After several hours she will mix the resulting sand with mercury, which binds to the gold in an amalgam. When the amalgam is heated, the mercury vaporizes, leaving the gold behind.

The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded photographer Cédric Gerbehaye's work covering COVID-19 in Belgium.

ILLUSTRATION BY JOE MCKENDRY

lured by the possibility of a lucky strike.

Luck comes to miners in dreams and in more insidious ways, says Maria Eugenia Robles Mengoa, a Peruvian-Bolivian anthropologist.

When Robles first traveled to La Rinconada in 2016, she found a *machista* world in which women nonetheless are omnipresent. For the miners, even Mount Ananea is female, she says. They call it *awicha,* which means "grandmother" in Quechua.

If a miner is lucky, the legend goes, a female spirit—*la gringa*—will visit him in dreams and guide him to a rich ore vein. But la gringa is considered jealous, and local belief holds that she will not give up her gold if another woman enters the mine. Even now, few women venture into the mountain.

There's also a disturbing belief that luck comes to miners who drink heavily and have sex with young women. In La Rinconada, some 2,000 young women, some of them minors, work in bars that double as brothels.

"When I first saw these girls and the violence they suffer, I felt a combination of rage and desperation," Robles recalls. At the time, she was 27, and all of these women she saw in La Rinconada were younger.

Conditions also are harsh for *pallaqueras*—women, often wives of miners, single mothers, or widows—who scavenge through piles of waste rock outside the mine entrances, collecting gold-bearing chunks. Although they perform an essential task for the claim holder by clearing away debris, the pallaqueras, who inhale rock dust and poisonous fumes as they search for whatever gold they can eke out of the discard pile, are among the most vulnerable workers in the chain.

Large amounts of ore often are processed with cyanide to extract the gold, but the smaller amounts gleaned by pallaqueras and by miners on their cachorreo days usually are crushed with mercury, which binds to the gold, forming a lump of amalgam. This may be done in a tumbler-like drum or with huge rocks in a tool called a *quimbalete.*

The miner or pallaquera then takes the amalgamated lump to a buyer who blasts it with a blowtorch to vaporize the mercury, leaving the gold behind.

Some gold shops use devices to capture the mercury, but shopkeepers and miners are still exposed to toxic mercury vapor, which also drifts over the glacier above La Rinconada, condensing on the ice and poisoning the drinking water supply. Globally, this kind of gold processing is the top source of anthropogenic mercury in the Earth's atmosphere.

BY THE TIME gold from informal mines in La Rinconada or other parts of Peru ends up in wedding rings or watches, it bears no traces of the harsh conditions in which it was produced.

Two La Rinconada miners wait to see what a local gold buyer will pay for their labors. In lieu of regular wages, miners are allowed to work roughly an extra day or two a month and sell what they find in a system known as *cachorreo*.

NAR DE ORO
INCONADA
Hombres Fuertes
METTLER TOLEDO

Some of the gold is sold through legal channels, but to avoid paperwork and taxes, some miners sell theirs on the black market.

Black market gold may be laundered, with paperwork to make it appear legal. As long as the papers appear legitimate, exporters may not inspect a mine to see whether it complies with regulations.

Eventually, most gold from Peru is exported to refineries abroad, with about one-third of exports going to Switzerland, which refines as much as 70 percent of the world's gold.

High gold prices have allowed once modest Peruvian brokers to become top exporters quickly. But pressure from environmental and human rights organizations and several high-profile cases have led to efforts to clean up the supply chain.

Those cases include Peruvian customs agents' seizure of a 200-pound shipment bound for Switzerland and arrests in the U.S. of refinery employees on money-laundering charges.

Cleaning up the supply chain means requiring miners to comply with regulations and enabling buyers to trace the gold to its source and verify the conditions there.

The task has been complicated by a surge in the number of unregulated mines in Peru as gold prices rose from less than $300 an ounce two decades ago to about $1,700 an ounce this spring. Unable to comply with regulations designed for large corporate mines, small-scale operators often have paid no taxes and received little official oversight.

Women known as *pallaqueras* watch a truck dump waste rock from a mine, which they will comb for chunks containing traces of gold. Mostly wives of miners, single mothers, or widows, they are exposed to bitter weather and accidents and sometimes face sexual harassment from mine foremen who give them permission to work.

During the past two decades, Peru's government has made various attempts to bring those miners into compliance with administrative, labor, and environmental regulations, but that process—known as formalization—takes time.

Of the more than 60,000 informal miners registered with the government, only some 1,600 have finished the process, which obliges them to pay taxes, obtain necessary permits, and manage environmental impacts.

The tens of thousands of other informal miners can sell gold legally as long as they declare that they are working toward compliance. The deadline for formalization has been extended several times, however, allowing the sale of gold that has been produced under harsh and dangerous conditions like those in La Rinconada or in placer mines that have left moonscape-like craters across Amazonian lowlands.

That's how gold that may have been chipped away by a miner on his cachorreo day, with all the health and environmental risks that implies, could end up in a wedding ring or a Swiss watch.

IF ANYTHING CAN CLEAN UP informal gold mining, it's consumers who insist on knowing that their jewelry is untainted by pollution or abusive labor practices, says Pachas, who is now country manager for Peru and Bolivia with the nonprofit Alliance for Responsible Mining (ARM).

ARM is one of three main organizations—the others are Fairtrade International and the Responsible Jewellery Council—that certify gold from miners who meet a series of legal, social, and environmental standards and link them with jewelers who want to be able to trace their supply to its origin. In addition to the market price, certified gold fetches a premium, which the miners reinvest in the mine or use for community projects, depending on their agreement with the certifying organization.

The Nobel Peace Prize medal has been cast from ARM-certified "fairmined" gold since 2015, and the Zurich Cantonal Bank sells Fairtrade International-certified bars made of gold from Peru. Ensuring traceability is labor-intensive, however, and because of a shortage of buyers willing to pay extra, the amount of gold certified as "fairtrade," "fairmined," or "ecological"—meaning that it was processed without toxic chemicals—is still just a tiny fraction of the total mined each year.

The Better Gold Initiative, a public-private association involving Switzerland's government and the gold industry, is trying to connect miners directly with large-scale jewelers and other manufacturers and increase demand among buyers.

Although 18 mines in Peru have been certified, the complex system of contracts and cachorreo in the underground mines of the world's highest settlement makes certification there especially difficult.

Even so, "it's not impossible," Pachas says. "It's a matter of the miners having the will to do it. And a matter of trust." ☐

Barbara Fraser reports mainly on environmental, public health, and Indigenous issues. **Hildegard Willer** is a journalist focusing on social and environmental issues. Both are based in Lima, Peru.

Conservation That Lasts

Without fenced-off reserves, can wildlife and nearby communities both thrive? In northern Kenya, the pandemic put the idea to the test.

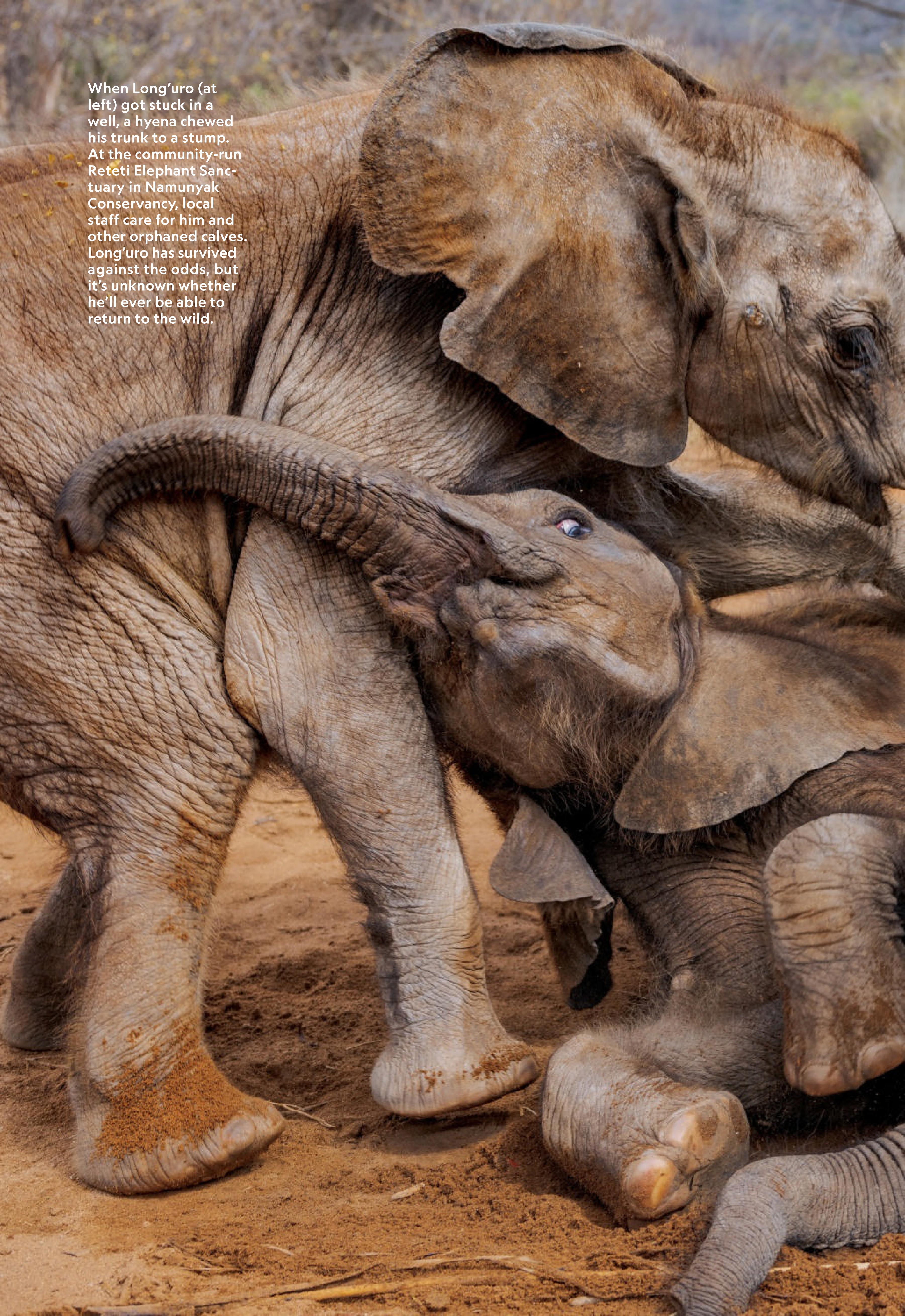
BY **TRISTAN MCCONNELL**

PHOTOGRAPHS BY **DAVID CHANCELLOR**

The sun burns off the morning mist from the valleys of Samburu County. The beauty of Kenya's north draws tourists, and the region is home to pastoralists, their livestock, and wild animals. They frequently compete for space, water, and pasture.

PREVIOUS PHOTO

At the Lewa Wildlife Conservancy, a team captures an endangered Grevy's zebra to help form a new herd at Sera Community Conservancy. Sera was established by local Samburu communities with support from the Northern Rangelands Trust (NRT), an organization funded largely by Western nonprofits and governments to promote community-led conservation.

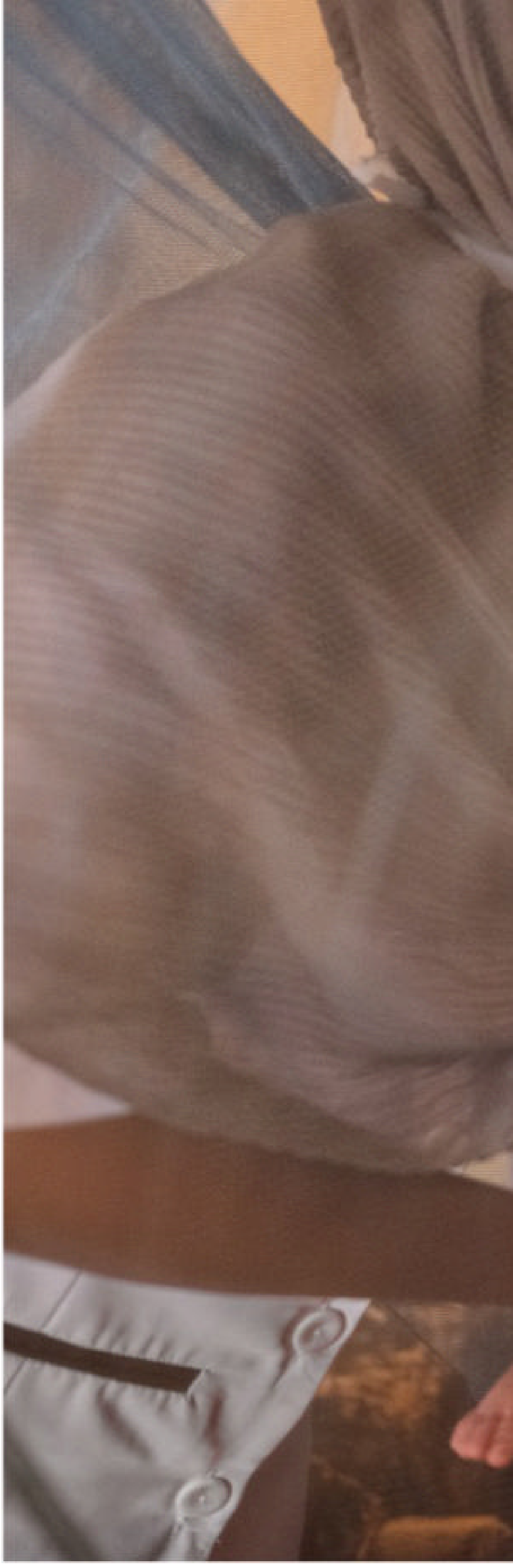


When Long'uro (at left) got stuck in a well, a hyena chewed his trunk to a stump. At the community-run Reteti Elephant Sanctuary in Namunyak Conservancy, local staff care for him and other orphaned calves. Long'uro has survived against the odds, but it's unknown whether he'll ever be able to return to the wild.

Outside the health clinic in Biliqo, a hot wind whips up the dirt.

It tugs at the shreds of material caught in the thornbushes, whirls discarded plastic bottles across the ground, and chases the tail of Madina Kalo's indigo hijab as she stands in the clinic's rough wooden doorway. It's midyear—northern Kenya's main dry season—and the land is parched by the sun, the color palette bright and blown out, like an overexposed photograph.

Kalo, dressed in her white nurse's tunic and surgical mask, squints, then steps back into the cool of the clinic. She sees about 30 people a day, most of them pastoralist herders reporting routine ailments such as respiratory infections, malaria, and diarrhea. When cases are serious, Kalo refers patients to the town of Isiolo, a five-hour journey on a gravel road.



Nurse Madina Kalo hands a newborn boy to his mother, Hadija Galma, at a clinic NRT built with European funds in Biliqo. "You have to start catering for the health of the people before you can start talking about conservation," Kalo says.

The trash and torpor of Biliqo do not inspire thoughts of tourism or nature, yet the town is in one of 39 community conservancies established by the Northern Rangelands Trust (NRT), a Kenyan conservation organization. In return for a promise to strengthen protection of their environment and wildlife, the people living in the conservancies receive basic services and benefits, often paid for by safari tourists' cash.

It's a large-scale experiment in coexistence, based on the idea that people and wildlife can thrive together. Across 17,000 square miles, hundreds of thousands of people, millions of livestock, and important populations of wildlife live side by side.

Roughly two-thirds of Kenya's wildlife live outside national parks and reserves, so conservancies have become a fundamental part of the national conservation ecosystem.

When COVID-19 closed borders and grounded planes, tourists disappeared from northern Kenya, as from elsewhere, denying Africa much of the income that wildlife tourism brings each year—$29 billion in 2018. In Kenya, tourism made up at least 8 percent of the GDP. There were fears that conservation gains made in recent decades would evaporate. Tourism supports much of this work, from rangers and research to steady jobs in areas where employment is scarce, offering an alternative to hunting animals or felling trees to make ends meet. Many in the conservation sector hold up community conservancies such as these as exemplars for the future of sustainable, community-led conservation and development, even as NRT faces criticism from some Kenyans who say it’s too big and powerful. As the community conservancy model comes into focus in northern Kenya, the pandemic represents its biggest stress test yet.

African conservation was in crisis even before the coronavirus. Funding shortfalls, poor management, poaching, habitat destruction, and climate change are among a long list of threats that have caused collapses in biodiversity and a plunge in populations of at-risk species such as hawksbill turtles, pangolins, white-backed vultures, and elephants.

To those of us living a romantic—and safe—distance from wild animals, they are part of a global natural patrimony: good to know they exist, wonderful to see in real life. But what if you live alongside them? What if a leopard kills your goat or an elephant tramples your child? What if you can’t pay your medical bills and school fees, but you know there’s a ready market for lion skins and elephant tusks? What if your family is hungry and a giraffe is just a hunt away? What, then, is wildlife worth alive? What is it worth dead?

NRT’s mission is to amplify living animals’ value to the people who share the landscape with them and in so doing, entwine their futures. Rooted in the ideals of community landownership and self-governance, each conservancy is a separate legal entity, and each is managed by an elected board of community leaders.

Some conservancies are closer to fulfilling these ideals than others. Boards must manage the often competing desires of their diverse and far-flung community members, including nomadic pastoralists who aren’t always around when decisions about land use are negotiated. Sometimes that feeling of exclusion falls along ethnic lines, exacerbating conflict. Conservancies with more representative and responsive boards are able to ensure greater buy-in from and benefits for the community, while others struggle to meet basic governance standards.

NRT owns no land itself and functions primarily as an umbrella organization, handling administration, fundraising, security training, and strategic planning. It’s betting that if the foundations of self-governance are in place, the institutions eventually will become stronger and more accountable.

Foreign donors, who provide 90 percent of NRT’s funding, supplemented by revenue from tourism, other commercial earnings, and some local government funding, have helped NRT weather the pandemic better than most tourism-dependent wildlife parks and reserves. Yet the donors—largely U.S.- and European-based organizations such as USAID, the Nature Conservancy, the European Union, and Flora & Fauna International—also have made NRT a target for those who see foreign money and influence as a form of imperialism.

“It’s an international NGO, even though it’s operating like a local NGO,” says Achiba Gargule, a researcher on community land issues who grew up as a pastoralist in northern Kenya.

Either way, NRT’s setup is creating the building blocks of a huge, interconnected ecosystem, one that’s less reliant on the ups and downs of tourism, more diversified in its income, and it turns out, more durable in the face of global shocks.

KALO’S CLINIC used to consist of two dilapidated buildings and a rickety gurney, but now there’s a new 10-bed maternity ward, a clinic building with consultation rooms, and soon, staff accommodations and a lab. The facility is owned by Kenya’s health ministry, paid for by European governments, and built by NRT in a pragmatic bid to win people over to its conservation agenda. It is a trade-off in which Kalo is a knowing participant.

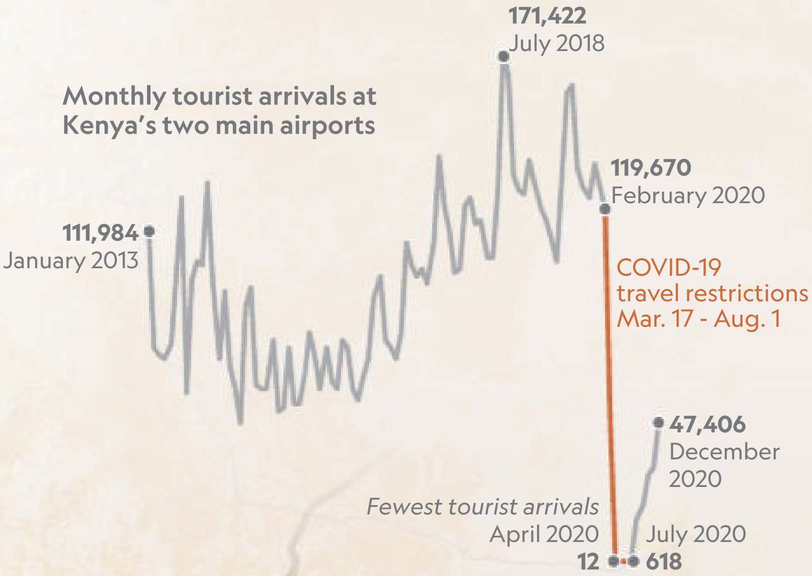
“Health is the most vital thing in each community,” she says as she registers the day’s patients. “You can’t talk to people who are not well. You have to start catering for the health of the people before you can start talking about conservation.”

Pastoralists are a fundamental part of Kenya’s arid northern landscapes. Fiercely independent and frequently armed, they move with their livestock in search of grass. Rivalry for scarce resources is intense and can turn violent. Livestock are a braided rope of meanings tying herders to the rangelands: Their cows, goats, sheep, and camels have cultural, social, nutritional, and financial value. A growing herd is a symbol of success and a shield against disaster. But livestock, like wildlife, need space to roam, grass to eat, and water to drink, meaning cattle and conservation frequently are in competition.

CHRISTINA SHINTANI, NGM STAFF. SOURCES: NORTHERN RANGELANDS TRUST; KENYA NATIONAL BUREAU OF STATISTICS; P. WANG AND OTHERS, HBASE DATASET, NASA SEDAC; ESA CLIMATE CHANGE INITIATIVE, LAND COVER PROJECT 2017; OXFORD COVID-19 GOVERNMENT RESPONSE TRACKER; DAVID CHIAWO

Resilient conservation

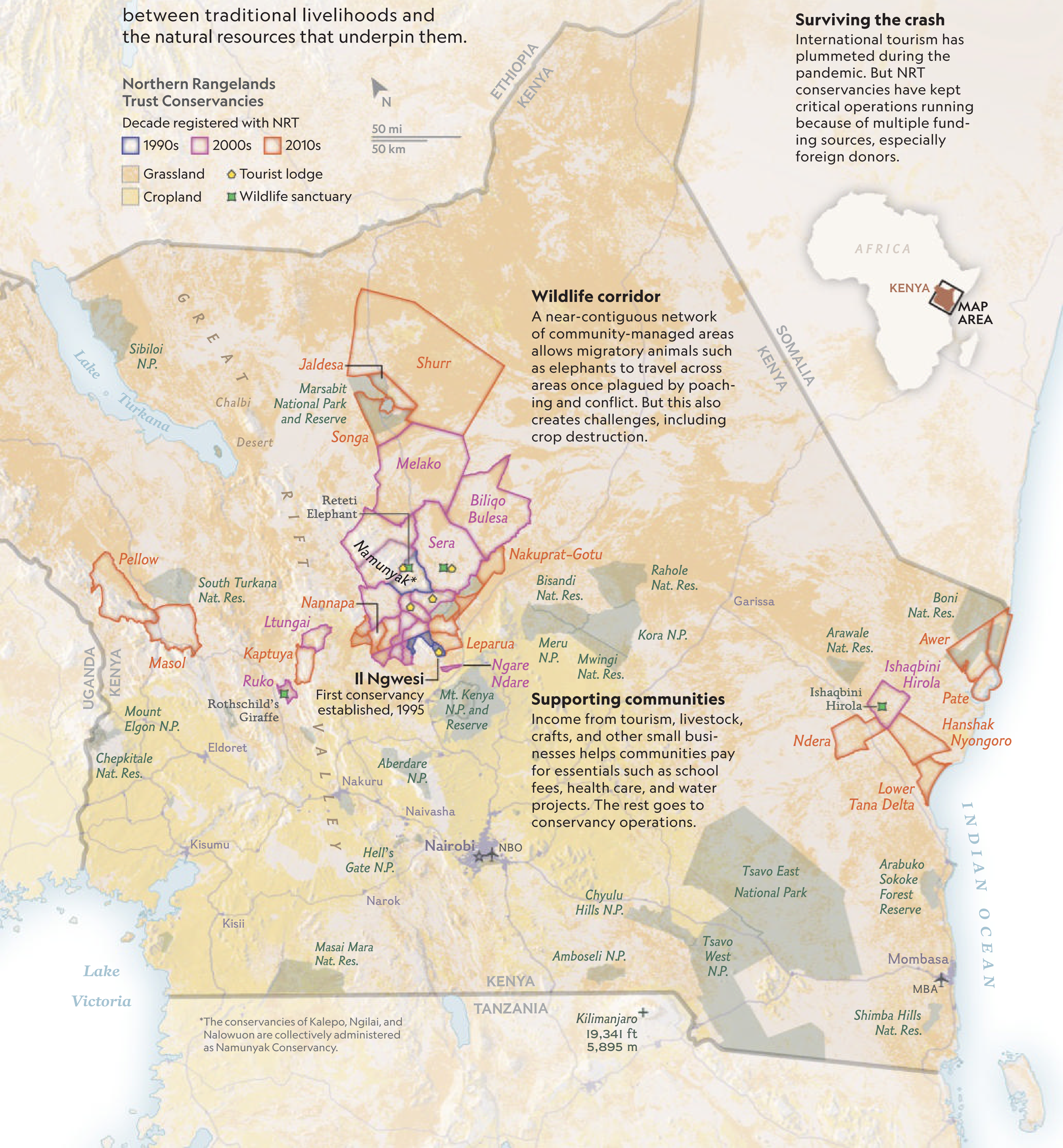
The Northern Rangelands Trust (NRT) is made up of 39 conservancies, owned and led by communities throughout northern Kenya. Representing nearly half a million people, mostly pastoralists, the conservancies help protect endangered species such as elephants and black rhinos. The community conservancy model—with fundraising and expertise provided by NRT—aims to find a sustainable balance between traditional livelihoods and the natural resources that underpin them.



Monthly tourist arrivals at Kenya's two main airports

Surviving the crash

International tourism has plummeted during the pandemic. But NRT conservancies have kept critical operations running because of multiple funding sources, especially foreign donors.



Wildlife corridor

A near-contiguous network of community-managed areas allows migratory animals such as elephants to travel across areas once plagued by poaching and conflict. But this also creates challenges, including crop destruction.

Supporting communities

Income from tourism, livestock, crafts, and other small businesses helps communities pay for essentials such as school fees, health care, and water projects. The rest goes to conservancy operations.

*The conservancies of Kalepo, Ngilai, and Nalowuon are collectively administered as Namunyak Conservancy.

> ‘We were fighting each other—the Samburu, the Rendille, and the Borana—but the conservancy started to bring us together.’
>
> *—Pauline Lolngojine, former chairperson, Sera Conservancy*

Following a Samburu initiation ceremony that marks the start of adulthood, a young elder, Sikitau Lenkees, dresses new warrior Lobulu Lekilemo with the beads of his clan. New warriors will spend up to 15 years herding cattle, sheep, and goats. Pastoralism in northern Kenya is under pressure from climate change and development. To support traditional livelihoods and create new opportunities, NRT promotes sustainable grazing and holds livestock markets, while also offering small-business loans, vocational training, and jobs.

Herders and cattle awake with the sunrise in Namunyak. Most NRT conservancies set aside some land exclusively for wildlife, and the rest is managed by grazing plans to improve rangelands. Directives on when and where cattle can graze, however, can become contentious, especially during drought, when good pasture is scarce.

18+

WHAT IS
AVAXHOME?

AVAXHOME -

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Cheap constant access to piping hot media
Protect your downloadings from Big brother
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All languages
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Finding a way for both to thrive is the challenge at the core of conservation in northern Kenya.

"Fences will never protect wildlife here in the north," says Tom Lalampaa, a Samburu conservationist and NRT's CEO. "You have to make sure it's the people who will become that fence." Whippet-gray vervet monkeys make feinting dashes at the door and windows as we speak. "If they can just look after wildlife the same way they look after their livestock, then it's a win."

It's also a work in progress. Conservancy boards are encouraged to set aside a portion of their land exclusively for wildlife. The rest is managed by plans developed by conservancy grazing committees and approved by community boards for the use of both livestock and wildlife. Directives on where, when, and how many livestock can graze, however, can become contentious, particularly among those who feel excluded from decision-making and see any restriction as a potential existential threat.

Hassan Roba, a drylands expert at the Christensen Fund, which supports Indigenous peoples and their landscapes, argues that these grazing plans compromise the flexibility of moving with the rains and often designate land for wildlife that is also the best pasture for livestock. "These are all very idealistic ways of thinking about how land is managed," he says. "But even in practice, the priority has been for the wildlife. Livestock is just an extra."

Wading through goats, a woman collects water from a borehole drilled by NRT in Biliqo Bulesa Conservancy. Wells and irrigation are among the services local conservancy boards choose to fund with tourists' daily fees, which also help cover the conservancy's operating costs. NRT derives additional income from foreign donors and local governments.

WITHOUT SECURITY AND SAFETY, for people and wildlife, nothing works. "Peace is everything," says Pauline Lolngojine, a single mother to 11 children (five her own, six adopted), a community leader, peacemaker, and former chairperson of Sera, an 840,000-acre NRT conservancy. We speak beneath the corrugated eaves of a timber-framed Pentecostal church in Archers Post, a town on Sera's southwestern fringe. When Lolngojine was growing up, northern Kenya was a wilder place, remote from the central authority of Nairobi and awash with weapons. Cattle rustling was rife, and road banditry was common.

"We were fighting each other—the Samburu, the Rendille, and the Borana—but the conservancy started to bring these communities together," she says. Sera formed in 2001, fostering cooperation and creating a shared objective with a shared benefit: improved land management and improved income. "We saw that it was good to conserve so that we can get money through these wild animals," she says.

The long-term investment in peacebuilding means that in hard times, such as a pandemic or a drought, there is an existing structure to defuse tensions and maintain stability.

Collaboration and money help, but security requires enforcement too, which takes the form of NRT's scouts and mobile ranger units. The mobile units were created to protect elephants and black rhinos, but the rangers' dual role as police reservists makes them an integral part of an overstretched and poorly funded regional security architecture. Able to respond to non-wildlife

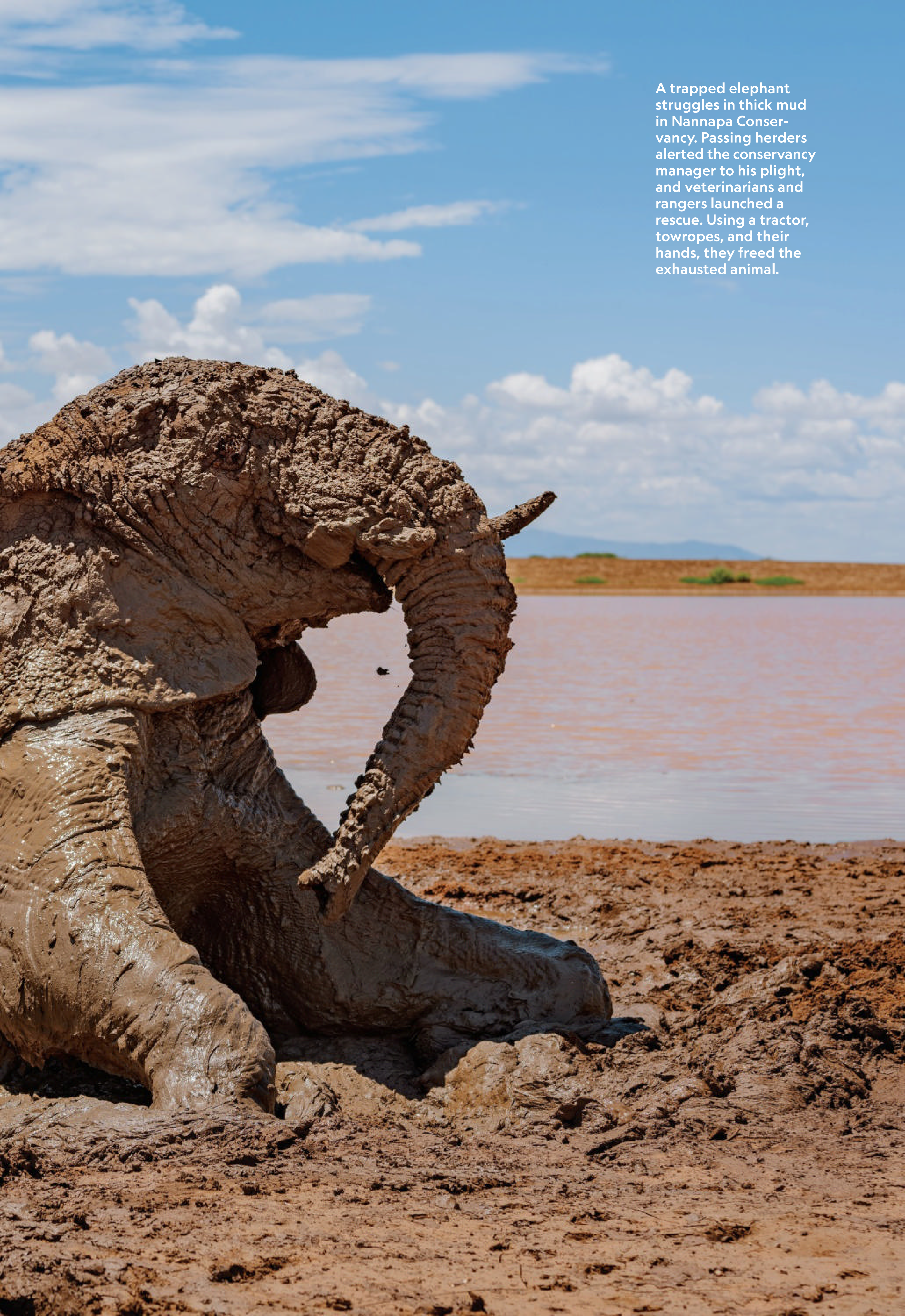
crimes such as livestock theft and highway robbery, they've helped fill a security vacuum.

Armed with rifles, they move 12 to a vehicle, resupplying on the go and sleeping beneath the stars. They earn at least $350 a month, more than double a ranger's normal salary. Each unit is made up of members of three to four different tribes, their multiethnic nature allowing the teams to go anywhere and talk to anyone.

Six feet six inches tall in his hefty desert boots, Losas Lenamunyi is a shorn-skulled, rangy man with a gap-toothed grin. (Predictably, he's known as Mrefu, meaning "tall," and his last name means "owner of rhinos.") The commander grew up herding livestock near the roadside shanty of Sereolipi, where ethnic Samburus often had only animosity and suspicion for the neighboring Borana, Gabra, and Rendille peoples. Today he shares a Land Cruiser with them. "I have all tribes in the car," he says.

Lenamunyi didn't go to school and says he never thought much about wildlife. He became a ranger for the money. "There was no opportunity of getting any job," he says. Being a ranger means "my children have food enough."

The desperation for jobs was clear at a ranger recruitment event in Melako Conservancy. Three positions were vacant, and 200 hopeful men turned up. They gathered beneath the doum palms on the southern bank of the river, dressed in plastic sandals and sarongs, with foot-long knives fixed to their belts and traditional



A trapped elephant struggles in thick mud in Nannapa Conservancy. Passing herders alerted the conservancy manager to his plight, and veterinarians and rangers launched a rescue. Using a tractor, towropes, and their hands, they freed the exhausted animal.

walking sticks in hand. "Educated people are the ones who get jobs," says Melako chairman Andrew Dokhole. "That is why [for] rangers, normally we pick from local people." He continues, "It is the only chance they have."

With more than 1,300 people working as rangers, administrators, and other staff in NRT conservancies, the organization is among the biggest employers in the north. (Lodge and tourism operators are also big employers.)

The organization is involved in so much that the Nature Conservancy's Matt Brown, an NRT board member, says, "NRT as a community-owned NGO is frankly doing the job of local government." It's not a role NRT wants permanently, he says, and it's a characterization that makes Lalampaa uncomfortable. Critics make the same case: They argue that NRT is a neocolonial project that undermines Kenyan sovereignty and usurps government responsibilities.

"NRT is supposed to be community led, community owned," Gargule says. "But what you're seeing is its links with very important and big conservation organizations worldwide."

To try to counter that criticism, NRT made the executive team and board of directors accountable to a council of elders, which is made up of the chairperson from each conservancy. There are questions about the power the council truly wields, but NRT insists its existence and prominence are important.

Lalampaa says NRT does not seek to replace government but adds, "Northern Kenya has had some gaps, and NRT's conservancies really helped to fill in."

Nonetheless, insecurity still plagues the region, especially during drought or following the generational cycle of circumcision rituals, after which boys become *morans*—warriors—set loose to prove themselves in the world, often through cattle raiding, fighting, and the like.

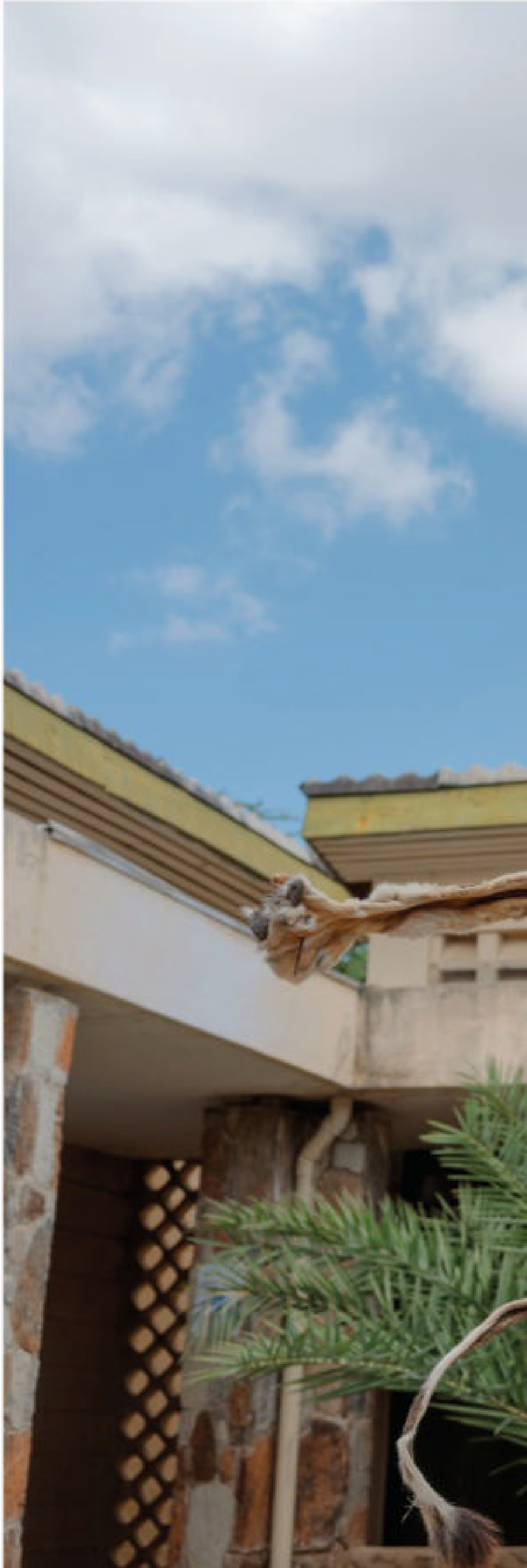
FOR MORE THAN A CENTURY, governments in Nairobi treated the north with scorn. Colonial British settlers had little interest in it, deeming the arid land not worth stealing for farms and ranches. Independence in 1963 brought a new ruling elite, dominated by southern Kenyans who took an equally dim view of northerners, whose itinerant pastoralist ways made them hard to govern.

This neglect left a hole that NRT helped fill, providing basic services in exchange for conservation. "The foundation of this is influencing people," says Ian Craig, one of NRT's founders and conservation director. "How can I influence you to align and affiliate with our thinking?"

It is an overtly transactional strategy.

Craig, 68, is both the driving force behind the trust and a focus of criticism as a white landowner of colonial descent. I hitch a ride with him in his canary yellow, single-engine Piper Super Cub to talk.

"It's a big bit of country," Craig says through a crackly headset as he guides the aircraft up the Rift Valley, a raw landscape of tectonic lakes, sharp escarpments, and volcanic outcroppings. As anvil-like thunderheads converge on the



A Kenya Wildlife Service ranger carries the dried skin of a lion that died of natural causes to storage. The service will lend it out for cultural ceremonies, such as initiations into adulthood, allowing traditions to continue without the need to kill more lions. Still, as some wildlife numbers have rebounded in conservancies and human populations have grown, conflict between the two is increasing.

valley's towering eastern shoulder and jagged forks of lightning leap from the sky, Craig jerks the two-seater plane left and right.

NRT was born out of Lewa Wildlife Conservancy, a 62,000-acre private wildlife reserve and onetime cattle ranch established by Craig's grandfather in 1922. When Craig inherited it some 50 years later, it remained a beautiful stretch of grassland and woods, gentle hills and sharp valleys, but it struggled as a ranch. "It was always in drought. We couldn't make any money; it was a disaster," Craig says.

In the early 1980s conservationists persuaded him to set aside 5,000 acres as a fenced sanctuary for black rhinos, which had been hit hard by poachers killing them for their horns. Elephant poaching for ivory also was spiking across Africa; perhaps tens of thousands killed each year. With rhinos sheltering in his backyard and elephants being slaughtered nearby, it was clear to Craig that Lewa would not survive in isolation. Human populations were growing, livestock numbers rising, wildlife species declining, landscapes deteriorating. If people were the problem, they must also be the solution.

In 1995, the year the Craig family transferred the rest of their ranch to Lewa, Craig persuaded the Laikipiak Maasai owners of a "group ranch" (a Kenyan land tenure structure in which residents share title over grazing lands) to shift focus. They agreed to set aside some of their land for wildlife protection and implement grazing plans for the

Wildebeests trudge across the burnt grasslands of the Masai Mara Game Reserve, which relies on tourism to fund its operations and conservation work. When COVID-19 halted foreign travel, many local staff lost jobs, and some were forced into activities such as illegal hunting. Less reliant on tourism, NRT community conservancies have proved more resilient during the pandemic.

rest, drawn by the promise of income from safari tourism. North of Lewa, Il Ngwesi's 22,000 acres of rocky scarps and wooded valleys drop from the Laikipia Plateau to the plains along the Ndare River. A new ecolodge opened the next year.

As the buffer zone around Lewa expanded, so did Craig's ambitions. Soon after came Namunyak. It includes the granite peaks and razor ridges of the Mathews Range, a 50-mile-long spine of forested sky islands jutting thousands of feet above the acacia and myrrh savanna. More conservancies followed.

The scope and scale grew until, in 2004, with funding from USAID, Craig helped establish NRT. Its mission: to connect and conserve huge landscapes, crisscrossed with wildlife migration corridors, in which people and their livestock could coexist with wildlife.

"The narrative of conservation is not a national park with animals," Craig says. "This model is about connectivity," he adds, referring to the mosaic of public national parks, private reserves, and community land in northern Kenya. "These little pockets of land, they're big, but they're just not big enough ... For wildlife to survive and breathe and grow, they need those communities."

And the communities, in turn, benefit from tourism. In every conservancy, tourists pay a conservation fee, which is split 60/40 between the conservancy's community programs and its operations—the former paying for things such as school fees, water projects, and medical bills; the latter for rangers, vehicles, and equipment. Rates vary, but foreign tourists commonly pay up to a hundred dollars a day, while Kenyan residents might pay a fifth of that.

NOWHERE IN THE NORTH has tourism potential been more profitably realized than at Sarara Camp, an ecolodge in the southern part of Namunyak. When Sarara was built in 1997, "there was no peace, not for humans and not for wildlife," says safari guide and driver Daniel Lenaipa, who grew up in the area. Security led to the return of elephants, leopards, wild dogs, and other animals, as well as the arrival of tourists. In 2019 visitors to Sarara paid some $350,000 in fees, enough to cover the entire budget for the entire southern part of Namunyak, and equivalent to nearly a quarter of tourism income to all of the trust's conservancies that year.

Then came the coronavirus. "For the last 10 or 15 years we have been having revenue going to the community, and for the first time we might not have anything going back because it purely comes from tourists," says Moses Lenaipa, a former Namunyak board member and current manager of the Reteti elephant orphanage in central Namunyak (Moses is Daniel's older brother).

I meet Namunyak's manager, Tom Letiwa, at Reteti on a scorching hot morning as baby elephants in a nearby stockade are hand-fed bottles of fortified goat's milk, bought from local women. "This year revenue will be very low," he says. Kenya's quick actions to slow the disease—including closing schools, making face masks mandatory, imposing a nationwide curfew, and restricting cross-border movement—meant that all Kenyans understood how serious the pandemic's impacts would be. Residents of Namunyak saw there were no tourists and knew there would be no money, Letiwa says.

NRT instituted pay cuts at headquarters and lobbied donors to keep rangers paid and conservancies' operational budgets untouched. Public funding also kicked in. County authorities created a $1.1 million annual fund to support the nine conservancies in Samburu County, and the national government included two million dollars for NRT ranger salaries as part of its COVID-19 stimulus plan.

Unlike some of the more tourist-dependent protected areas such as the Masai Mara Game Reserve in western Kenya and the national parks, northern Kenya has not seen a significant increase in illegal hunting or encroachment for grazing, farming, or building since the start of the pandemic.

That's not only because emergency funding helped rangers stay on patrol. The success of community conservation in bringing benefits beyond tourist dollars has helped prevent the economic desperation that would force people to turn to such activities. Still, NRT conservancies did see an uptick in non-environmental crimes, including cattle theft and road banditry. They may have ridden out the pandemic better than others, but they certainly felt the consequences of job losses and livestock market closures.

Meanwhile, populations of endangered elephants, oryx, reticulated giraffes, and Grevy's zebras are stable or increasing in NRT conservancies. Elephant poaching is down, and the animals are ranging farther and more freely,

Populations of endangered elephants, oryx, reticulated giraffes, and Grevy's zebras are stable or increasing in NRT conservancies.

though that has also led to an increase in retaliatory killings of elephants that are now more likely to trample crops or even kill people.

At the same time, overgrazing hasn't disappeared entirely, but having grazing plans that are backed by a conservancy's board has given local leadership some authority to enforce a policy that aims to promote a greater good over short-term self-interest.

Critics such as Gargule argue that NRT leadership pressures community boards to carry out its conservation goals, whether or not those goals are beneficial for everyone. "NRT is so powerful that it can actually influence anything within the conservancies," Gargule says. "But how much of [the community's] voice is heard?"

Craig acknowledges that influencing communities to protect wildlife is what NRT is all about. That's where the trade-offs come in: Is the benefit of attracting an ecolodge worth setting aside land and pasture for wildlife? Is it worth following a restrictive grazing plan in exchange for a school and clinic? How much use of its natural resources is a community willing to forgo, and what does it gain in return?

In an uncertain world, developing new and reliable sources of funding is crucial. "COVID-19 means there is risk everywhere, but it is also an opportunity to reset, to lift the conservation agenda," says Giles Davies, founder of Conservation Capital. The investment group finances projects that help protect landscapes around the world, including in Davies's home country of Kenya, where he has worked with NRT. "We need to shift the conversation from how to survive to how to thrive."

During an early morning walk with his pack of dogs near his home in Laikipia County, Davies tells me that the scale and governance of NRT's conservancies put it in a rare position to attract investment from capital markets as economies rebuild, including from environmental corporate social responsibility funds. "The base is there to bring in the real economics, at scale, to bring sophisticated capital markets thinking to the frontier," he says. "NRT isn't a government. It's a platform for financing."

Evidence of the potential to rope together huge tracts of land, attract funds, and share the benefits already is emerging through carbon offsets. A group of 14 conservancies is part of a soil carbon credits project that stands to bring in millions of dollars. "The whole thing depends on people's adherence to the grazing plans," says Stephen Wood, a soil scientist at the Nature Conservancy who has worked on the project for the past four years. Preventing overgrazing allows the grasses to recover and to trap more carbon in the ground, he says.

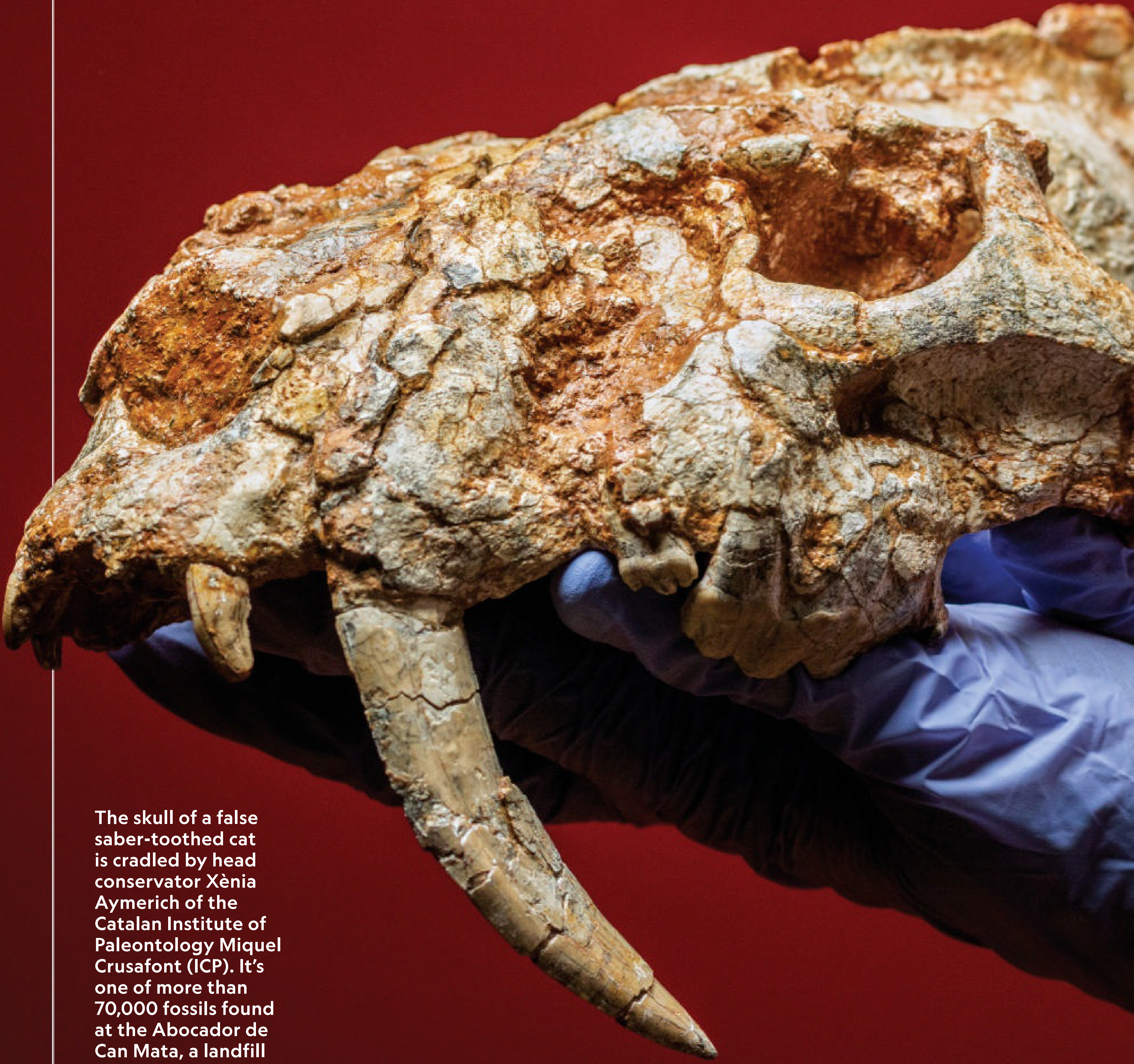
Corporations that want to reduce their carbon footprint can offset their emissions by buying carbon "credits" from those with huge landholdings. For the conservancies, the ability to sell carbon credits can encourage good rangeland management and reduce dependence on capricious donors and fickle tourists. "The rates per acre are very small," Wood says, "so what makes a project like NRT work is the ability to stitch together very large acreage to get scale."

Running NRT and its 39 conservancies cost seven million dollars in 2020, an amount Craig says is "a pittance" given NRT's broad aims. "This is petty cash in real terms for the impact on the number of lives in our footprint."

Those lives include the mothers, children, and elderly men queuing in the sun outside Kalo's new clinic in Biliqo. They include the pastoralist herders for whom the risk of raiding has been reduced thanks to Lenamunyi and his ranger colleagues. They include the young men at Melako dreaming of a job as a ranger. And they include Daniel Lenaipa, in Namunyak, who knows that as COVID-19 ebbs, the tourists will return because security is reliable, wildlife is thriving, and the landscape is protected. □

Tristan McConnell lives in Nairobi and is writing a book about the Rift Valley. **David Chancellor** has spent years documenting conservation throughout Africa. This is his second story for the magazine.

THE **PRICELESS FOSSILS** IN THE **GARBAGE DUMP**



The skull of a false saber-toothed cat is cradled by head conservator Xènia Aymerich of the Catalan Institute of Paleontology Miquel Crusafont (ICP). It's one of more than 70,000 fossils found at the Abocador de Can Mata, a landfill near Barcelona that's a paleontologists' paradise.

As a landfill expands in Spain, paleontologists are uncovering many ancient species, including some that were the precursors to apes—and us.

BY **JENNIFER PINKOWSKI** PHOTOGRAPHS BY **PAOLO VERZONE**

Can Mata is the largest active landfill in the Catalonia region of Spain, and it keeps getting bigger. Fed up with the smell and noise, many locals want it closed. But each expansion offers paleontologists access to fossils deep underground that would otherwise be out of reach.

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The soil at Can Mata holds fascinating fossils from about 11.2 million to 12.5 million years ago, including species of ancient primates found nowhere else in the world. Paleontologists have been monitoring the dump's expansion since 2002.

FEWER PLACES ARE LESS WELCOMING THAN A GARBAGE DUMP ON A FRIGID NIGHT.

BUT THAT'S WHERE paleontologist Josep Robles found himself in December 2019, on the hunt for rare clues to human evolutionary history.

For much of the past couple of months, he'd spent several nights a week at the Abocador de Can Mata, the largest active landfill in the Catalonia region of Spain. Seven days a week, 24 hours a day, excavators had been plunging their metal claws into the earth in a rush to create yet another deep pit to hold trash from Barcelona and its surroundings. Robles was one of eight paleontologists on rotation to keep a close eye on the rocky tons of tawny dirt displaced by the diggers.

During the day, the sickly sweet aroma of rot drew squawking flocks of gulls; the dirt, as soft and fine as powdered sugar, rose in small clouds with Robles's every step. At night he dressed in heavy layers, a headlamp strapped to his hard hat. Whenever he spotted a mass that seemed to have potential, he waved to the excavator operator to pause while he investigated the object more closely.

If it still looked promising, he covered it with light-catching silver foil for removal in the morning, by light of day. Then he'd back away, give the all clear, and the roar of the machine would begin once again.

The soil of Can Mata holds a wide array of fossils spanning more than a million years in the Miocene, from about 11.2 million to 12.5 million years ago. Since 2002, Robles and other paleontologists from the Catalan Institute of Paleontology Miquel Crusafont (ICP), at the Autonomous University of Barcelona, have found more than 70,000 fossils from this period. They include those of horses, rhinoceroses, deer, elephant relatives called proboscideans, an early kin to the giant panda, and the world's oldest flying squirrel. There's also a wealth of ancient remains from rodents, birds, amphibians, and reptiles.

But among the most important discoveries are fossils of

Alba Rico Barrio is among the scientists who have flocked to the dump over the years to help unearth its prehistoric riches. The fossils emerging from Can Mata so far represent more than 85 mammal species, plus about 15 species of birds, amphibians, and reptiles.

ICP

primate species found nowhere else. Many are broadly ancestral hominoids—the precursors to gibbons; to great apes, including orangutans, gorillas, and chimpanzees; and to us. During the middle Miocene, there were dozens of hominoid species. They had originated in Africa, but by 12.5 million years ago, they'd also appeared in Asia and Europe. The primate bones found at Can Mata are helping to fill in the picture of a period deep in our past that, in many ways, remains murky.

"Can Mata has enabled us to show that primates were much more diverse in that time span than considered before," says ICP director David Alba.

And each new fossil clue helps us unravel some of the most profound mysteries of our species: What are we? Where did we come from? And when did we begin to be?

LOCATED ABOUT 30 miles northwest of Barcelona, Can Mata landed on the primate fossil map in the early 1940s when Miquel Crusafont, namesake of the ICP, discovered the partial mandible and teeth of a Miocene great ape at the site. Subsequent finds helped establish Can Mata as a documented paleontological site. Despite its status, it also has operated legally as a landfill since the mid-1980s.

In the early 2000s, when site operator Cespa Waste Management wanted to dig new trash-holding cells at least 100 feet deep, the company was obliged under the Spanish Historical Heritage Law to make sure its machines weren't crunching through fossils or burying them beneath mounds of trash. Cespa approached some fossil-spotting scientists to supervise the excavations, and they jumped at the chance to access the dump's depths.

In 2002, freelance paleontologists (now all with the ICP) Isaac Casanovas-Vilar, Jordi Galindo, and Alba—who was then a Ph.D. student—began monitoring the dig at Can Mata. Three weeks into the work, they unearthed the tooth of a dinothere, an enormous elephant relative with downward-curving tusks. Investigating the spot more closely, they found a fragment of a finger bone. "I was like, man, this looks like a primate," recalls Alba.

He ran to his car and retrieved a cast of the hand of the extinct ape *Hispanopithecus,* which had been discovered in a nearby valley. The paleontologists compared the two but were still unsure what they'd found. Next they found three fragments of a canine tooth, which Alba glued together, and a cache of tiny, fragile bone fragments scattered near a block of sediment. Camera in hand, Alba lay on his stomach to get a better look at the underside of the block.

He was shocked to realize he was eye to eye with an ancient face. "The three of us, very nervous—we were barely speaking—turned it up," he says. "And there was the face of *Pierolapithecus* looking up at us. So it was one of the biggest moments in my life."

Pierolapithecus catalaunicus, nicknamed Pau, is what they'd eventually call the new species of great ape they'd discovered. About 12 million years old, it's one of the most complete Miocene primate skeletons ever found. The team went on to unearth additional bones from the animal's chest, lower back, and wrists. It's the oldest known primate fossil to show unambiguous evidence of a characteristic unique among apes and humans: an orthograde—or upright—body plan.

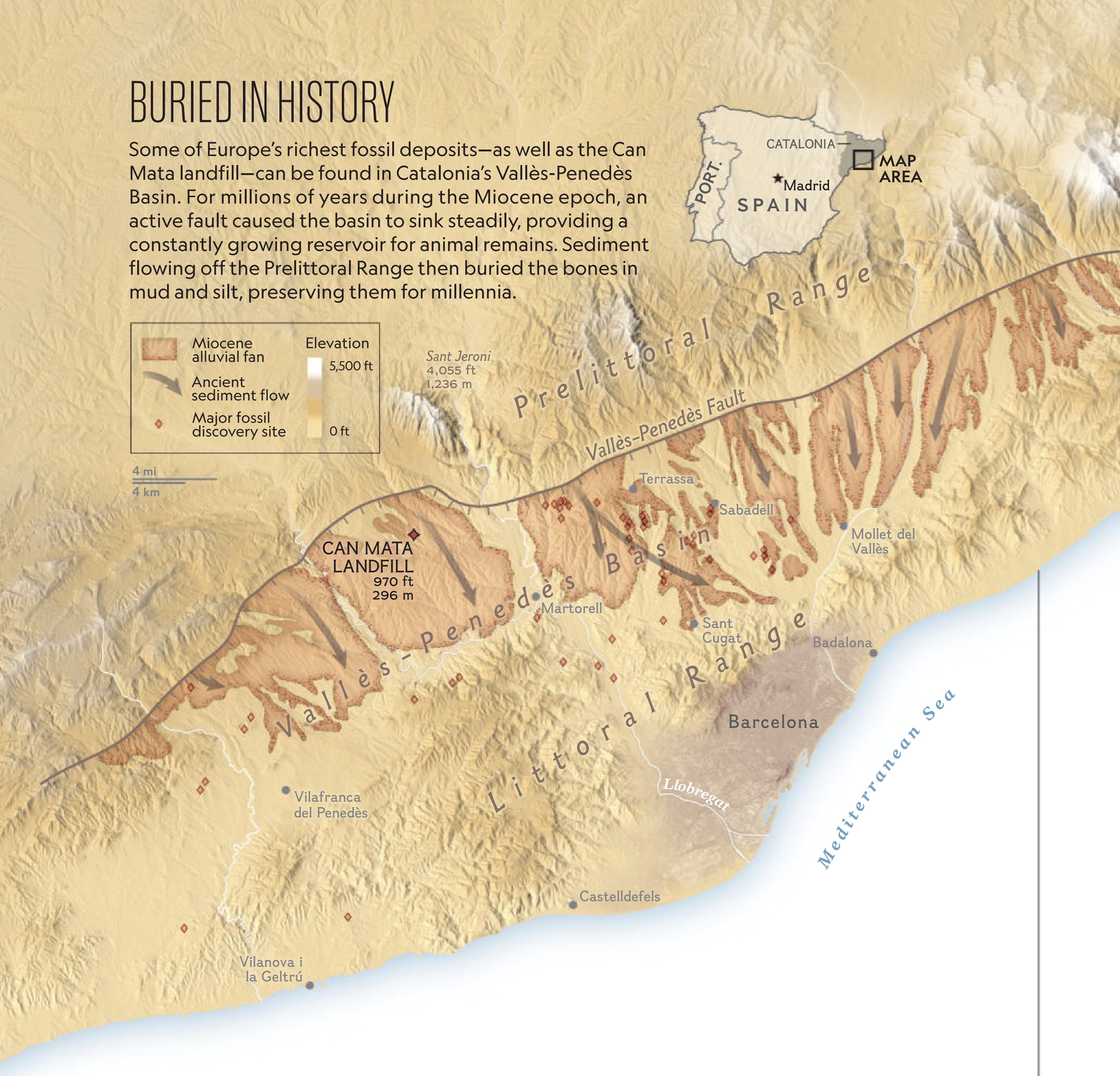
"This is not to be confused with biped," Alba notes. "Some people use upright to mean biped. This is plain wrong."

Instead, the orthograde body plan enables vertical climbing, suspending from branches, swinging from tree to tree, and sometimes walking on two feet. While some of these

EACH NEW FOSSIL CLUE HELPS US UNRAVEL SOME OF THE PROFOUND MYSTERIES OF OUR SPECIES: **WHAT ARE WE? WHERE DID WE COME FROM? AND WHEN DID WE BEGIN TO BE?**

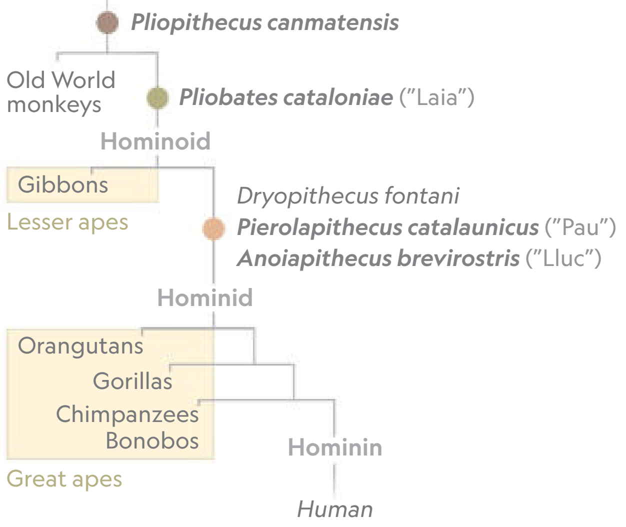
BURIED IN HISTORY

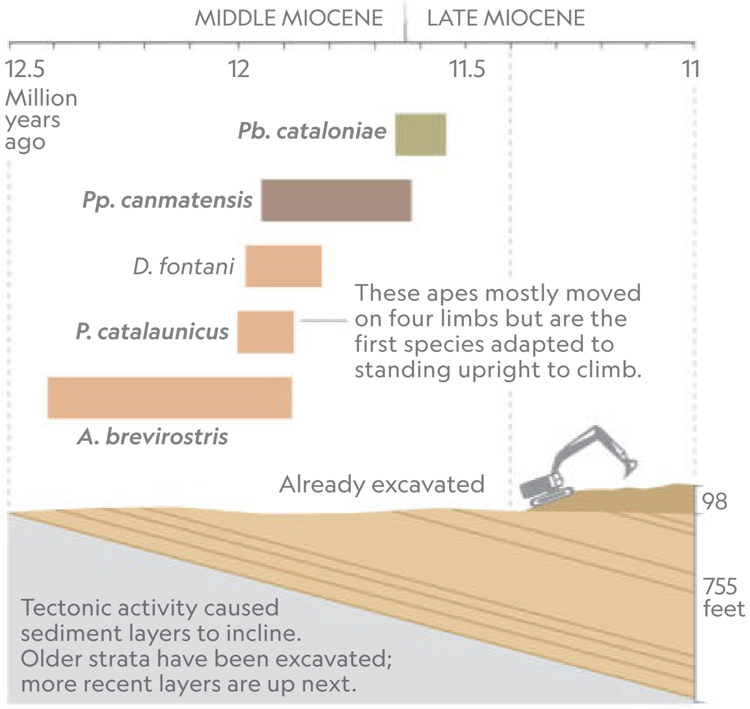
Some of Europe's richest fossil deposits—as well as the Can Mata landfill—can be found in Catalonia's Vallès-Penedès Basin. For millions of years during the Miocene epoch, an active fault caused the basin to sink steadily, providing a constantly growing reservoir for animal remains. Sediment flowing off the Prelittoral Range then buried the bones in mud and silt, preserving them for millennia.



FIRST FINDS

The region's once forested, humid conditions were ideal for ancient primates. Four species (shown here in ***bold***) were first discovered in Can Mata, and as excavations continue, scientists expect to find more primates.


Pliopithecus canmatensis
Old World monkeys
Pliobates cataloniae ("Laia")
Hominoid
Gibbons
Lesser apes
Dryopithecus fontani
Pierolapithecus catalaunicus ("Pau")
Anoiapithecus brevirostris ("Lluc")
Hominid
Orangutans
Gorillas
Chimpanzees
Bonobos
Great apes
Hominin
Human



These apes mostly moved on four limbs but are the first species adapted to standing upright to climb.

Tectonic activity caused sediment layers to incline. Older strata have been excavated; more recent layers are up next.

ROSEMARY WARDLEY AND DIANA MARQUES, NGM STAFF
SOURCES: DAVID M. ALBA AND ISAAC CASANOVAS-VILAR, CATALAN INSTITUTE OF PALEONTOLOGY MIQUEL CRUSAFONT; EU-DEM

Once removed from the landfill, fossils are stored at ICP headquarters in Barcelona, where they wait to be prepared and studied. Here, conservator Jordi Galindo checks the labels on bundles of fossil-laden earth encased in polyurethane foam.

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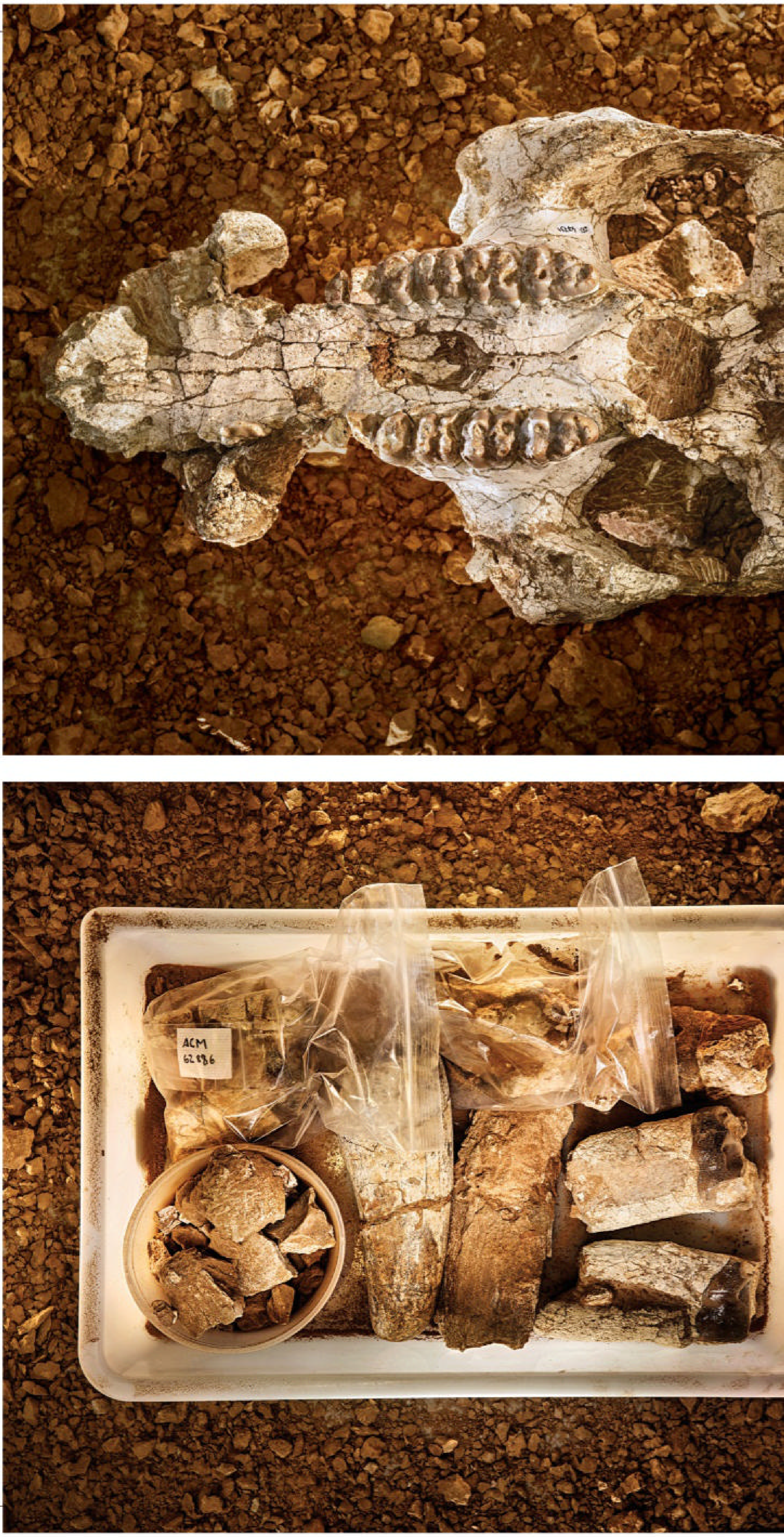
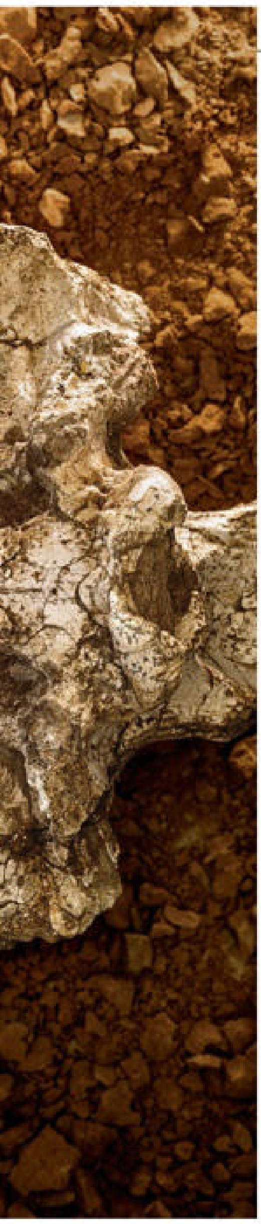


The diverse bones and teeth from Can Mata include (clockwise from top left) remains from an extinct pig, a mouse deer, a giant tortoise, and an ancient elephant relative. Variants of chemicals in the fossils, called isotopes, hold clues to the region's past climate, such as changes in rainfall and temperature. Carbon isotopes also indicate the types of plants or prey the animals once ate.



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behaviors likely evolved several times independently, the orthograde body plan might have evolved only once, or perhaps twice. According to Alba and his colleagues, the Pau fossil suggests the last common ancestor of all hominids might have been orthograde. If so, that may offer a hint at what gave certain species an evolutionary edge.

The team at Can Mata also was thrilled to find another new hominoid called *Anoiapithecus brevirostris,* dating to roughly 12 million years ago. Most primate faces protrude, but the face of this fossilized male, nicknamed Lluc, was intriguingly flat—so much so that it seems reminiscent of faces in our own genus, *Homo.* The researchers proposed that this was the result of convergent evolution, in which similar characteristics evolve in unrelated or distantly related organisms.

Then in 2011 came the fossil of a female *Pliobates cataloniae,* nicknamed Laia. This newfound species lived about 11.6 million years ago—about half a million years later than Pau. She was tiny, weighing about the same as a house cat, but paleontologists were surprised to find that she had a few ape features, such as her gibbon-like wrist bones and skull shape.

Understanding the roots of great apes is important for figuring out the origins of hominins, the taxa that arose after our lineage and chimpanzees' split from their common

Álex Pérez, collections manager of Barcelona's CosmoCaixa science museum, examines the fossilized bones of *Pliobates cataloniae,* one of the ancient primates unearthed from Can Mata. This diminutive species shows that some early ancestors of modern apes and humans were much smaller than scientists had thought.

ancestor six million to eight million years ago. The human lineage "did not appear out of nowhere," Alba says. "So we need to know where they did evolve from."

THE FOSSIL GOLD MINE in the garbage dump has yielded more than 85 mammal species that lived alongside these prehistoric primates.

One recent find is a *Chalicotherium,* a tall, clawed ungulate that looks like a bizarre mix of giant sloth, bear, horse, and gorilla. Another is a false saber-toothed cat, so called because it's not a true felid, the family that includes lions and tigers. Instead, it belonged to a family of carnivores that diverged from the ancestors of felids perhaps 40 million years ago.

The fossils all date to an important transitional period from the middle to the late Miocene, when the region's subtropical rainforests were becoming more arid and grasslands expanded. The scientists are using these finds to help reconstruct Can Mata's environmental changes over about a million years, in time slices of 100,000 years. That resolution is possible because Can Mata has a long, continuous geological record.

"It's several hundreds of meters of sediments, all with fossils," says ICP's Casanovas-Vilar. This work is just beginning, but the researchers hope to illuminate the local impact of global climate change—in both the past and the present.

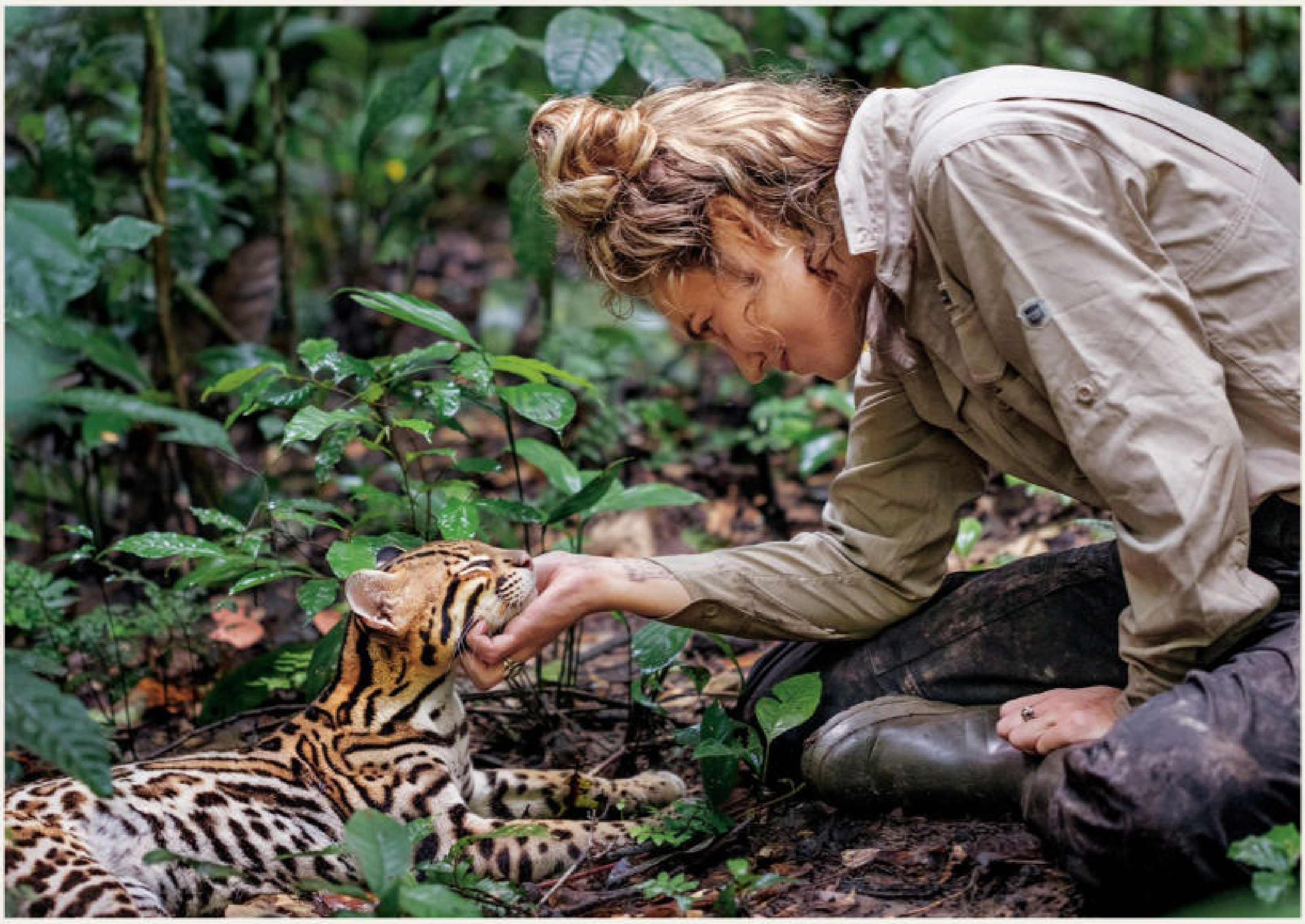
"Ecosystems can tolerate changes for a time, but for how long? That's one question that we can answer or that we'll try to answer for this particular environment and this particular time," Casanovas-Vilar says.

The big question is whether digging will be possible in the decades to come. Some residents have had it with Can Mata—its ripe stench, its endless procession of exhaust-spewing garbage trucks, its ongoing expansion. In fall 2019, even as Robles and his colleagues monitored the excavators, protesters gathered at the dump entrance holding signs written in Catalan. *Prou pudors. Tanquem l'abocador. Volem respirar en pau.* "Enough stink." "Close the landfill." "We want to breathe in peace."

Yet in a recent referendum locals approved the dump's expansion, potentially through the end of the decade. So the scientists won't leave anytime soon. They also have plenty of work ahead on the fossils they've already unearthed. Only 20 percent of their finds have been cleaned of hardened sediment and chemically preserved. Thousands more are cocooned in brown paper and plastic wrap in cool, underground storage rooms. Numbered and labeled, each bundle waits for a curious researcher to unwrap it. Some have been waiting nearly 20 years.

"This is something for the next three or four generations of paleontologists," Alba says. "I'm sure there are interesting fossils hiding here." ☐

Journalist **Jennifer Pinkowski** is a New Yorker based in Berlin covering science and history. Photographer **Paolo Verzone** previously focused on dinosaur fossils, in the October 2020 issue.



INSTAGRAM

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FROM OUR PHOTOGRAPHERS

BABY PICTURE

Keanu the ocelot, at five months old. PHOTO: TREVOR BECK FROST AND HARRY TURNER

One of our most popular Instagram images ever (left) is this 2018 portrait of an ocelot cub named Keanu that had been rescued from the illegal wildlife trade in Peru. At a rehabilitation center in the Peruvian Amazon, ecologists Samantha Zwicker and Harry Turner helped the growing ocelot transition from care in an enclosure to life in the wild. One day in 2020, Zwicker (above) found Keanu with a puncture wound on his leg, likely from an encounter with a caiman or another ocelot. Zwicker cleaned the wound and nursed Keanu back to health. He returned to the wild a month later and hasn't been seen since.

This page showcases images from National Geographic's Instagram accounts—the most popular brand on Instagram. Join more than 230 million followers: **@natgeo, @natgeotravel, @natgeointhefield, @natgeoadventure, @natgeoyourshot.**

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